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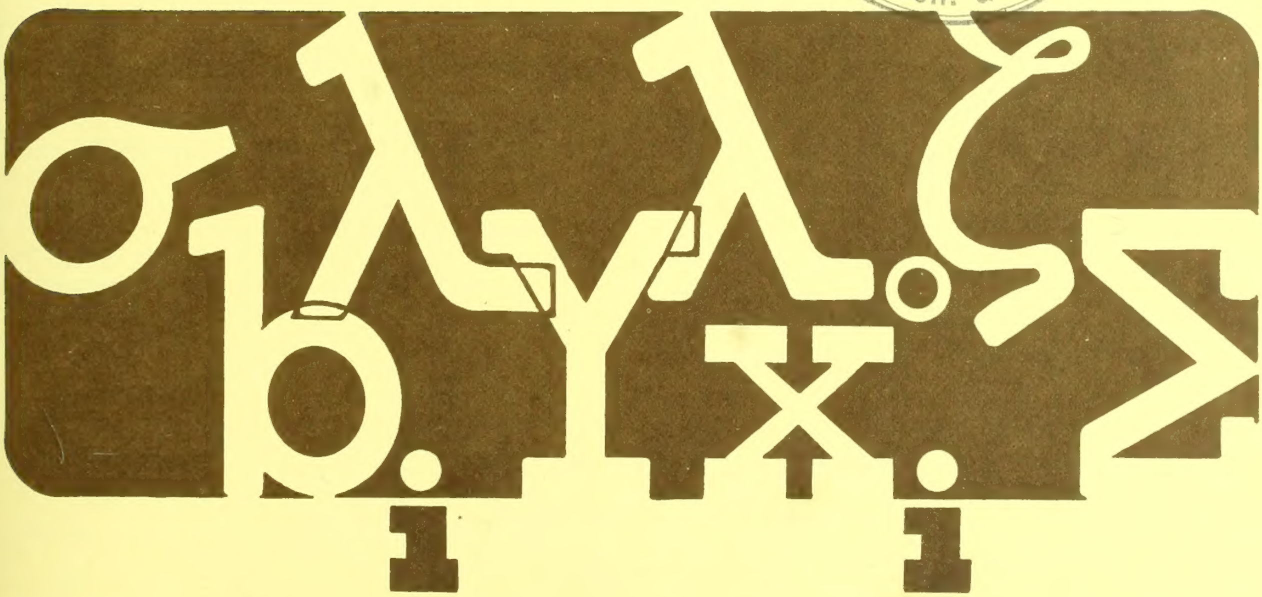
introduction to uses and interpretation of principal component analysis in forest biology

by J. G. Isebrands and Thomas R. Crow



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CONTENTS

Introduction 1
Principal Component Analysis 1
Historical Development 1
Basic Properties 2
Terminology and Notation 3
Operational Sequence 4
Examples of Applications 5
Discarding Variables 5
Ordinating Groups of Variables 8
Multiplotting 11
Principal Components in Conjunction With Regression Analysis 12
Literature Cited 17
Other References 19

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INTRODUCTION TO USES AND INTERPRETATION OF PRINCIPAL COMPONENT ANALYSIS IN FOREST BIOLOGY

J. G. Isebrands and Thomas R. Crow

INTRODUCTION

There is a definite need to acquaint those interested in, yet unfamiliar with principal component analysis (PCA), regarding its terminology, underlying assumptions, practical applications, and literature so that PCA might find more widespread and proper use in data analysis. Although most multivariate textbooks (e.g., Rao 1952, Kendall 1957, and Seal 1964) adequately cover the theoretical aspects of PCA, examples of practical applications with information concerning the interpretation are lacking in the literature. Adding to the confusion for the beginner is the proliferation of matrix notation and the lack of standardization among texts in both notation and terminology.

Our objective is to introduce PCA to the forest biologist who has had an exposure to introductory statistics, and likely applies ANOVA, correlation, and regression routinely, but who has not made the jump to multivariate techniques. Our intent is to demonstrate through detailed examination of two applications the utility of principal component analysis in helping solve research problems in forest biology.

It should be emphasized that PCA is normally not used to test a null-hypothesis or in the estimation and prediction of quantities. Instead, it is an exploratory technique for assessing the dimensions of variability and aiding in the generation of hypotheses to be tested in conjunction with other statistical techniques such as multiple regression (Pearce 1969). Among the many potential uses of PCA in forest biology, those which will receive emphasis in this paper are: (1) reduction of the number of variables by deletion of extraneous variables; (2) ordination of variables as an aid to the interpretation of multivariate data; and, (3) use of PCA in conjunction with regression analysis for the identification of biological variables for further experimentation.

PRINCIPAL COMPONENT ANALYSIS

Historical Development

Principal component analysis (PCA) is certainly nothing new; mathematical statisticians have studied it for years (Hotelling 1933, Rao 1952, Kendall 1957, Anderson 1964, Seal 1964). As research tools the initial development and application of multivariate techniques are rooted in the behavioral sciences. The classical example is Spearman's (1904, 1927) attempt to prove his psychological theory that intellectual performances are a function of a single general mental capacity. The origins of PCA can be traced to variance-maximizing solutions in psychological and educational studies (Hotelling 1933). Recent emphasis given multivariate techniques is associated with the availability of computers to process the extensive calculations associated with the techniques. Almost every computer center now has one or more multivariate packages (e.g., Dixon 1970).

In forest biology, applications of PCA have been relatively few, although there has been a flux of recent publications. J. N. R. Jeffers (1962, 1964, 1965, 1967, 1970, 1972)

has been the greatest proponent of the use of multivariate analysis. Jeffers and Black (1963) applied PCA to 9 lodgepole pine provenances using 19 variables; they concluded that many fewer than 19 variables were needed to discriminate among provenances. Namkoong (1967) also used PCA for an analysis of provenance data in conjunction with regression.

Gessel (1967) recommended the application of PCA to aid in the assessment of the many factors that influence forest productivity, or yield. In an example, eighteen variables were tested against the productive capacity as measured by site index from a series of western hemlock (*Tsuga heterophylla* (Rafn.) Sarg.) stands in Washington State. Four uncorrelated components were found to have a major influence on the patterns of variation in productive capacity (Gessel 1967). Others have also utilized PCA to assess production relationships. Kinloch and Mayhead (1967) investigated the use of PCA to help assess the possibility of using ground vegetation as an indicator of productive potential in forestry. Decourt *et al.* (1969) used PCA and regression analysis with orthogonalized variables to elucidate the relationships between environmental factors and production in Scotch pine (*Pinus sylvestris* L.). PCA was employed by Vallée and Lowry (1972) to classify black spruce (*Picea mariana* (Mill.) B.S.P.) forest types and to help estimate site quality. Auclair and Cottam (1973) employed PCA and multiple regression analysis to assess the influence of environmental factors on the radial growth of black cherry (*Prunus serotina* Ehrh.).

In other forestry related areas, PCA has been used in dendrochronology (Fritts *et al.* 1971, LaMarche and Fritts 1971), palynology (Webb 1973, 1974a, 1974b), and geoecology (Newnham 1968).

Basic Properties

Principal component analysis is an analytical procedure for transforming one set of variates into another set of component variates having the following properties: (1) they are linear functions of the original variates; (2) they are orthogonal, i.e., independent of each other; (3) the total variation among them is equal to the total variation in the original variates, consequently, information concerning differences among the observed variates is not lost in transformation; and, (4) the variance associated with each component decreases in order--the first variate will account for the largest possible proportion of the total variation, the second will account for the larg proportion of the remainder, and so forth.

Bearing these properties in mind, a comparison of PCA to another popular multivaria technique, factor analysis, is appropriate. Within the literature, there is a great deal of conflicting terminology; as a result the distinction between PCA and factor analysis can be confusing. For example, where the term "factor analysis" has been applied to all multivariate procedures dealing with the reduction of dimensionality and identificati of common factors, PCA is often presented as a "factor analysis" technique. In other cas such as the IBM Scientific Subroutine Packag PCA is labeled as "principle component facto analysis."

Two important distinctions exist betwee PCA and factor analysis:[1]

(1) In factor analysis, p original variates are reduced into $m<p$ uncorrelated "factors" having an uncorrelated residual component; in PCA, p correlated variates are transformed into p uncorrelated variates, not all of which are necessarily significant.

(2) Unlike PCA, factor analysis has th potential for rotating the orthogonal axes that represent "factors" to new oblique positions so that theoretical postulations inherent in a model can be tested.

The first of these distinctions has to do with property No. 3 above. An assumptio basic to PCA is that the observed variation is caused by the effects that the underlying (casual) factors have on each of the origina variates. PCA, therefore, is a closed model without regard to random error or variation external to the system (Pearce and Holland 1960); thus, all variation in the original variates is accounted for by the derived variables. In factor analysis, however, only a portion of the total variation is attributed to the $m<p$ transformed variates (this portio is termed the "communalities") and the remaining variance is considered an error variance.

1/ *For details see Kendall (1957), Pearce and Holland (1960), Seal (1964), Cattell (1965), and Pearce (1965).*

Although the factor analysis model may seem more desirable for biological applications, the need to estimate communalities poses a problem because it requires *a priori* knowledge of the system. Initial estimates of communalities often are little better than arbitrary guesses; thus, a series of iterations is necessary before the investigator is satisfied. As a result, the model is developed to fit the data (Kendall 1957). In PCA, however, the process is reversed: one works from the data toward a hypothetical model. Beginning with the observations, the investigator develops a model that reduces the dimensions of variation, which consequently aids in the biological interpretation (Kendall 1957).

It must be emphasized that the variates--principal components--derived using PCA may not have any biological significance. Multivariate techniques must not be considered as a mode for the automatic generation of hypotheses, rather as an initial step in which complex data sets are simplified to make them more amenable to interpretation. Any hypothesis developed using PCA that seems plausible can only be considered subjective until confirmed by existing biological knowledge or additional studies (Pearce 1965).

Terminology and Notation

It is not necessary for the user to understand all aspects of PCA derivation. He must, however, have an overview of its terminology and notation if he is to effectively use PCA.

For example, suppose that $x_1, x_2, x_i \ldots x_p$ are random variables and that $\underset{\sim}{x}$ is a row vector composed of the x's. From this population, a sample of n independent observations can be drawn so that

$$\underset{\sim}{X} = \begin{bmatrix} x_{11} \cdots\cdots x_{1p} \\ . \\ . \\ x_{n1} \cdots\cdots x_{np} \end{bmatrix}$$

where $\underset{\sim}{X}$ is an n x p data matrix of full rank (i.e., independent rows and columns) (Morrison 1967). The variance-covariance matrix of $\underset{\sim}{X}$ is defined equal to S and the correlation matrix of $\underset{\sim}{X}$ is R.

The principal components are defined as linear combinations of the original x_i variables under consideration and are denoted by ζ_i, i = 1 ... p. The ζ_i have the form

$$\zeta_i = a_{i1} x_1 + a_{i2} x_2 + \ldots + a_{ip} x_p$$

$\underset{\sim}{A}$ is defined as a column vector and is referred to as an "eigenvector" (or latent vector) having coefficients a_{ij}. The coefficient subscript i refers to the eigenvector number and the subscript j refers to the original variable (x_i) number.

Each eigenvector ζ_i has a variance associated with it called an "eigenvalue" (or latent root) and is denoted by λ_i, i = 1 ... p.

Geometrically, we have a data scatter of n points in p dimensions and PCA is a rotation of axes such that the total variance of the projections of the points onto the first axis is a maximum (i.e., first principal component). The second axis (second principal component) is chosen orthogonal to the first and accounts for as much as possible of the remaining variance. Each additional axis is also orthogonal and accounts for a maximum portion of the remaining variation (Seal 1964). The linear combinations ζ_i are the length of the projections onto the new axis, and the directional cosines of the projections are the eigenvector coefficients a_{ij}. The variance of the projection is the eigenvalue (λ_i) (Seal 1964, Krzanowski 1971).

The algebraic and matrix derivation of the principal components, ζ_i and their variance is beyond the scope of this paper. However, it has been covered in detail in the literature (Hotelling 1933, Kendall 1957, Anderson 1964, and Morrison 1967).

The following properties of PCA are of importance for interpreting our examples. As stated earlier, the variance of each principal component (ζ_i) is its eigenvalue (λ_i); furthermore, the λ_i values sum to the total variance in the experiment. Therefore,

$$\lambda_1 + \lambda_2 + \lambda_3 + \ldots + \lambda_p = \sigma_1^2 + \sigma_2^2 + \sigma_3^2 + \ldots + \sigma_p^2$$

This means that the total variation of the derived variates equals the total variation of the observed variates, thus information is not lost by linear transformation.

In addition, the quantity

$$\left(\frac{\lambda_i}{\Sigma\lambda_i}\right)100$$

where $\Sigma\lambda_i$ = trace S (i. e., sum of diagonal elements of the correlation matrix) gives the percentage of the total variance explained by the i^{th} principal component (table 1). The cumulative percent of the total variance is also important because it refers to that portion of the variance "explained" by a particular eigenvector in question plus all previous eigenvectors.

Table 1.--*Eigenvalues, and cumulative percentage of variation associated with the eigenvalues from principal component analysis of 4-year white spruce nursery measurements*

	Eigenvalues (λ)	Cumulative percent of variation
1	10.07	0.530
2	2.25	0.648
3	1.63	0.734
4	1.08	0.791
5	1.05	0.846
6	0.56	0.875
7	0.50	0.902
8	0.49	0.928
9	0.31	0.945
10	0.29	0.950
11	0.23	0.971
12	0.18	0.981
13	0.13	0.988
14	0.09	0.992
15	0.06	0.996
16	0.03	0.998
17	0.03	0.999
18	0.01	0.999
19	0.01	1.000

Operational Sequence

The mathematical operations of PCA are important, but they represent only one aspect of the analysis. The entire spectrum of operational sequence follows:

(1) Selection of preliminary variables; (2) if necessary, transformation of original variables to meet the assumptions - ε's normally and independently distributed with mea 0 and variance σ^2; (3) selection of either the variance-covariance or the correlation matrix and calculation of that matrix; (4) determination of eigenvalues (latent roots) and eigenvectors of the variance-covariance or correlation matrix; and (5) interpretation of derived components.

The first step, variable selection, is extremely important. These variables should be quantitative characters, and preferably be measured on a continuous scale, although many discrete variables (e.g., the number of teeth measured along a leaf margin) adequately approximate continuous variables (Jeffers 1964).

The second step requires deciding whether to transform data, which admittedly can be a subjective decision (Jeffers 1964); in most statistical analyses, the assumption of normality is often neglected. Tests of significance are only meaningful for data that are multivariate-normal in their distribution and transformations may be necessary if normality is not present (Andrews, Gnanadesikan, and Warner 1971). Furthermore, Bartlett's test can be used for testing the homogeneity of variance. However, Jeffers (1964) recommended the use of transformations only when the data severely violate the assumptions, because transformations make the eventual interpretation of PCA more difficult.

The third step calls for another decision whether to use the variance-covariance matrix or the correlation matrix. Normally, if all units are of the same scale (e.g., all units of length), the use of the variance-covariance matrix is recommended. Use of the variance-covariance matrix has the greatest statistical appeal because the sampling theory is less complex than the others (Anderson 1964). However, if the units are mixed (e.g., length, volume, weight), normalization is necessary and the correlation matrix is used. The eigenvalues (variance) associated with an eigenvector from a correlation matrix is a standardized variance. Throughout this paper the correlation matrix is used.

The fourth step involves the linear transformation of p original variates into

p "artificial" variates. This is the mathematical equivalent of determining the eigenvectors and related eigenvalues of a variance-covariance or of a correlation matrix (Jeffers 1964). Conceptually this requires the extraction of common variables (i.e., the eigenvectors) and their variances (i.e., eigenvalues) from the variance-covariance or correlation matrix. A simplistic development of the mathematical derivation of eigenvectors and eigenvalues can be found in Pearce (1969); more complete derivations can be found in any matrix algebra text.

The fifth step involves the interpretation of the derived components. First, a decision has to be made regarding the number of components that have biological significance. There are various criteria to aid in this decision; in general, the elimination of those vectors that do not meet the criteria can be done with conviction. Admittedly, some subjectivity is involved in this process, but this is inherent in all statistical decisions. The next part of the interpretation process is the analysis of the eigenvectors that are deemed significant.

However, one must be cautioned that even after this operational sequence, there still remains the question whether a biological interpretation can be derived from the mathematical artifact. To interpret derived variables, one must be able to relate them to observed variables. To do this there are several accepted ways, which are explained in the example beginning on p. 5.

EXAMPLES OF APPLICATIONS

Discarding Variables

Among the PCA methods for reducing the dimension of a data set by discarding variables, we have found the method of retention outlined by Jolliffe (1972) most useful. The following example demonstrates the use of this method.

In 1958 a range-wide study of white spruce seed sources consisting of 28 provenances originating throughout North America from Alaska to New Brunswick (table 2) was established at our nursery near Rhinelander, Wisconsin. After 4 years' growth, 19 variables were measured on trees from each provenance (table 3). The large number of variables was considered necessary because of the preliminary nature of the study. Information derived from the study was to be used to help determine the usefulness of certain parameters for possible selection indices. These parameters would then be studied further in subsequent experiments. Portions of the data have been published (Nienstaedt 1968, Nienstaedt and Teich 1971).

The data consists of a 19 x 28 matrix suitable for the use of PCA in discarding variables. Bartlett's test of homogeneity indicated that the 19 variances are homogeneous at the 0.05 probability level, and therefore, no transformations are necessary. We continue the discarding procedure by calculating the 19 x 19 correlation matrix from the original data matrix and run PCA on it. See table 1 for the 19 eigenvalues (λ_i) and the cumulative percentage of the total variation "explained" by each.

Next we choose an arbitrary value, called λ_o, which has associated with it at least the cumulative proportion of the total variance that one wishes to "explain" in the analysis. This procedure is somewhat analogous to choosing the probability level that one wishes to operate at in a routine analysis of variance. Therefore, it depends not only upon the experimental material, but also upon experience of the scientist. Jeffers (1964) recommended choosing $\lambda_o = 1$ for biological data. If we choose $\lambda_o = 1$ in this example, we would expect to "explain" approximately 85% of the total variation (table 1) because there are 5 eigenvalues greater than 1.0 and their cumulative percent of variation is 84.6. The subset of λ's that are greater than λ_o is of size p_1; thus, there are also p_1 eigenvectors associated with these p_1 eigenvalues. In this example, $p_1 = 5$.

In examining the eigenvalues after PCA it may be necessary to distinguish between marginal eigenvalues (λ_i). Lawley (1956) showed that the degree of difference between eigenvalues can be measured by the ratio of the geometric mean of the eigenvalues to the arithmetic mean, which is distributed as χ^2. This procedure was outlined by Holland (1969).

The discarding procedure is continued by associating one or more of the variables

Table 2.--*Provenance values of the first 3 eigenvectors used for ordination of the white spruce example*

Source number	Location	Latitude	Longitude	Eigenvector number 1/	2	3
1	South Dakota	44-10	103-65	1/0.86	-3.54	-2.30
2	Montana	46-48	109-31	-6.31	4.64	0.22
3	Manitoba	49-51	99-30	1.26	-3.98	2.39
4	New York	44-23	74-06	10.70	0.11	-0.81
5	Wisconsin	45-41	89-07	8.09	-3.52	0.74
6	Minnesota	47-33	94-09	9.03	1.38	0.44
7	Minnesota	47-33	94-10	9.45	-7.21	0.52
8	New Hampshire	44-51	71-26	8.17	3.36	-0.02
9	Alaska	65-21	144-30	-23.08	0.58	0.77
10	Alaska	63-45	144-53	-13.10	-2.65	0.09
11	Alaska	66-35	145-11	-15.98	-2.08	-1.73
12	Maine	44-50	68-38	8.92	8.91	-1.00
13	Labrador	52-36	56-26	-6.66	5.46	3.00
14	Labrador	53-46	60-05	-5.00	3.21	2.36
15	New Brunswick	47-50	68-21	6.99	5.70	-4.75
16	Quebec	46-32	76-30	8.99	-0.01	0.13
17	Quebec	48-18	71-22	5.42	3.66	-0.52
18	Ontario	48-00	81-00	16.53	0.27	3.90
19	Ontario	45-44	76-51	12.38	-5.67	-0.20
20	Manitoba	54-39	101-36	-3.67	-3.16	-3.73
21	Saskatchewan	59-19	105-59	-8.50	-1.76	-1.70
22	Yukon	60-49	105-35	-18.51	-1.21	1.73
23	Minnesota	47-33	94-08	5.59	-2.83	-1.51
24	Michigan	44-30	83-45	4.46	-0.52	2.09
25	British Columbia	54-00	123-00	-2.80	0.96	-1.07
26	Manitoba	56-56	92-51	-16.12	0.62	-0.08
27	Ontario	52-15	81-40	-0.98	-0.47	1.24
28	Ontario	48-30	89-30	3.88	-0.25	-0.21

1/ Calculation procedure for each value:

$$\sum_{1}^{j} \{ ((x_{ij} - \bar{x}_j)/s_j) \cdot a_{ij} \}$$

under consideration with each of the p_1 eigenvectors mentioned above (Spurrell 1963, Beale *et al.* 1967, Namkoong 1967). This involves choosing the coefficient or coefficients having the highest absolute value in each eigenvector starting with the first eigenvector. Table 3 shows coefficients for the five eigenvectors (components) associated with the first five eigenvalues ($\lambda_0 = 1$; $p_i = 5$). The variables circled in table 3 should be retained. In our example, four coefficients in eigenvector 1, which accounts for 53 percent of the total variation, are candidates for having the highest absolute value in the vector because they are approximately equal (0.300): height (x_1); diameter (x_2); branch length (x_4); and bud length (x_7). Therefore these variables are retained.

Next consider eigenvector 2. The largest coefficient in this vector is 0.410 and is associated with bud color (x_6); therefore, bud color is retained. In eigenvector 3 the highest coefficient is associated with number of adaxial stomata (x_{13}); in eigenvector 4 with incidence of second flushing (x_{18}); and in eigenvector 5 with needle color (x_{11}). These variables are also retained.

The sign of the largest coefficient can be either positive or negative because the highest coefficient is chosen on

Table 3.--*Variables measured from 4-year-old white spruce provenances and the first five eigenvectors from the principal component analysis*

List of variables	Eigenvectors (A_i) 1	2	3	4	5
x_1 Height (in.)	0.303	-0.057	0.053	-0.088	0.137
x_2 Diameter (mm)	0.305	0.034	-0.013	-0.010	-0.051
x_3 No. of branches in top whorl	0.236	0.002	0.087	-0.248	-0.431
x_4 Branch length in top whorl (mm)	0.298	0.004	-0.032	0.009	0.177
x_5 Bud shape	0.176	0.376	-0.195	-0.085	-0.065
x_6 Bud color	0.164	0.410	0.044	0.211	0.215
x_7 Bud length (mm)	0.302	0.084	-0.048	-0.003	-0.126
x_8 Needle length (mm)	0.195	-0.312	-0.271	-0.257	0.021
x_9 Needle shape	-0.232	-0.009	0.314	-0.234	-0.166
x_{10} Needle rigidity	0.286	-0.116	-0.014	-0.006	-0.016
x_{11} Needle color	-0.045	0.268	0.255	-0.429	0.581
x_{12} Needle curvature	0.195	0.181	0.424	0.288	0.000
x_{13} Stomata (adaxial)	-0.006	-0.269	0.665	0.025	-0.060
x_{14} Stomata (abaxial)	0.216	-0.367	0.190	-0.154	0.199
x_{15} Needle serrulation	-0.235	-0.196	-0.197	0.029	0.349
x_{16} Branch surface	-0.266	0.000	0.001	-0.008	-0.346
x_{17} Sterigmata length (mm)	0.225	-0.276	-0.089	-0.269	-0.018
x_{18} Second flushing	0.101	-0.342	-0.031	0.620	0.154
x_{19} Forking	-0.273	-0.159	-0.061	-0.092	0.144

the basis of absolute value. Furthermore, the variables associated with the eigenvectors cannot be ones that are already associated with an earlier vector. When this occurs, the second largest coefficient is chosen. Questions have been raised about using this approach. However, Brown, Douglas, and Wilson (1971) showed that the coefficients of the original variables in the eigenvectors are not affected by the intercorrelation of the x's; therefore, the largest coefficient approach is valid.

The 8 variables we have retained--height, diameter, branch length, bud color, number of adaxial stomata, needle color, and amount of second flushing--are those to be considered in further experimentation. All others are discarded. This means that in our example, x_3, x_5, x_8, x_9, x_{10}, x_{12}, x_{14}, x_{15}, x_{16}, x_{17}, and x_{19} are rejected (table 3).

In this particular example, we happen to have hindsight as to the nature of the variables. Furthermore, those retained for further consideration appear to apply biologically. The first eigenvector can be considered a vector of size, because bud length at nursery age, height, diameter, and branch length all are important indicators of growth. This indicates that bud length and branch length may be as important as the traditional measurements--height and diameter--for distinguishing nursery age provenances. The retention of bud color and needle color also seems logical because both are important distinguishing characteristics of nursery-age white spruce. Needle color is particularly important in distinguishing the western provenances where introgression with Engelmann spruce has occurred. Similarly, the retention of second flushing is logical because it is an indicator of the latitude of the origin of white spruce, which can be related to the number of growing days. Second flushing is, therefore, an indicator of growth potential of white spruce.

The retention of number of adaxial stomata indicates that needle anatomy

data may be useful. However, the utility of anatomical data as selection indices must be weighed against the time and expense of collecting such data.

Ordinating Groups of Variables

Ordination, the ordering of units within a multidimensional space, has had widespread application in many other ecological studies and has potential for application in many other biological areas. The use of ordination is consistent with the desire to simplify and code a diversity of information so the underlying patterns of variability within a large data set can be more easily grasped.

When the entities (in this example, the 28 provenances of white spruce) are cast into this multidimensional hyperspace using the eigenvectors and associated components as axes (X-axis corresponds to the first eigenvector, Y-axis to the second eigenvector, etc.), the distance among these points is proportional to the degree of dissimilarity in terms of a set of variates (i.e., properties, measured parameters, characters). Thus an ordination has occurred. Furthermore, if discrete subpopulations with some degree of biological integrity can be defined, a classification can be obtained.

Using the white spruce data we obtained a PCA ordination as demonstrated by Jeffers and Black (1963). For each original variate of a given provenance, a standardized variable (which is the difference from the mean of all provenances divided by the standard deviation) was obtained and multiplied by the appropriate eigenvector coefficient found in table 3. Summation over all the variables

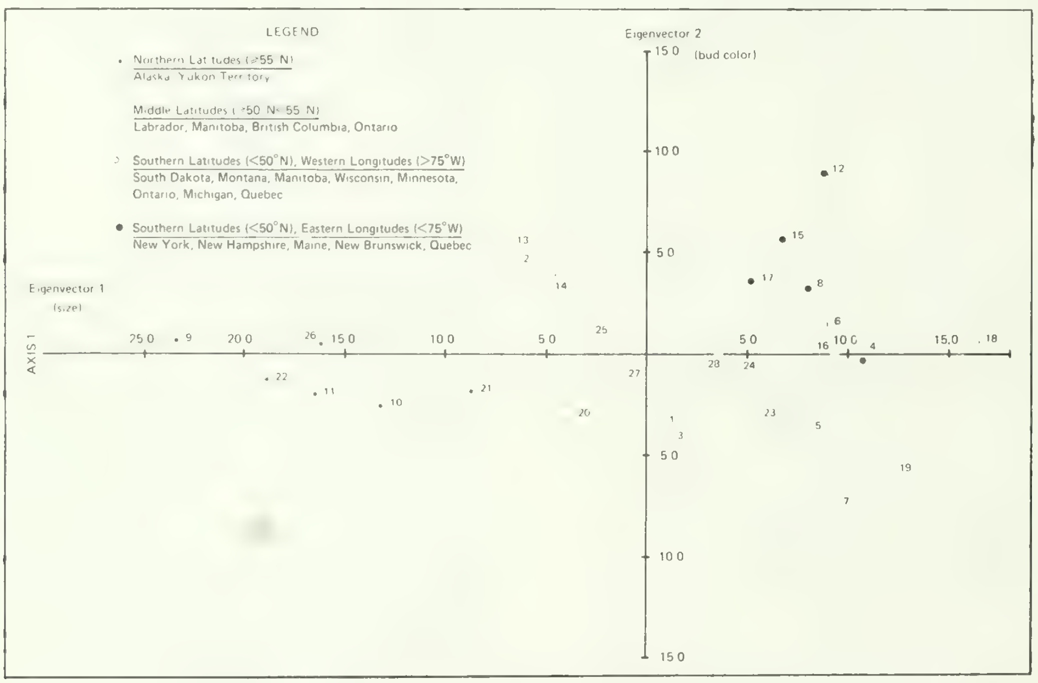

Figure 1.--*Ordination of white spruce provenances along two axes corresponding to eigenvector 1 (size) and eigenvector 2 (bud color). The position of each point is determined by the provenance values given in Table 2. The number associated with each plotted point is the source location number listed in Table 2. From a visual perspective, this figure can be considered a two-dimensional "side view" of an ellipsoid in three-dimensional space.*

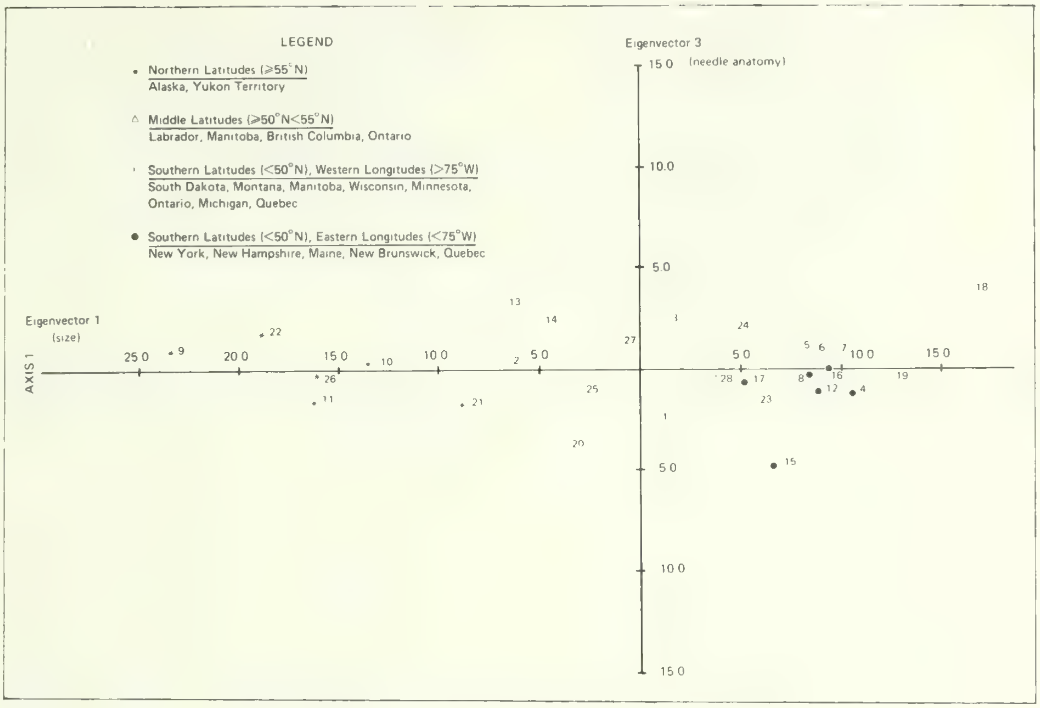

Figure 2.--*Ordination of white spruce provenances along eigenvectors 1 (size) and 3 (needle anatomy). This figure can be considered a "top view" of the ellipsoid.*

in the eigenvector then provides the numerical value for each provenance found in table 2 and plotted in figures 1, 2, and 3.

The most striking characteristic of the ordination of the white spruce data is the elongated form of the hypersolid. This confirms the importance of the first component (the size factor). This also suggests that the underlying dimensions of variability can be represented by far fewer than 19 variables with little or no loss of information.

The ordination is largely dependent on the first component--size--and the order of points in figure 1 corresponds to changes in latitude and corresponding elements such as length of growing season, temperature regime, and photoperiod; all affect the expression of the genotype (i.e., the phenotype) of a source and thus affect performance as measured by size in a provenance study. From left to right in figure 1, the first group of points is made up of provenances from the highest latitudes and the northwestern portions of the white spruce range; the second group is from the middle latitudes, and those to the right of the second axis (eigenvector 2) are from the lower latitudes and the southeastern portion of the range. In terms of size the poorest performers are on the left in figure 1, progressing in an orderly fashion along the first axis to the best performers on the right.

The second component--bud coloration--is important in discriminating among the eastern seed sources. Note the vertical spread in the points of the right quadrants (fig. 1). The ordering of points suggests the possibility of clinal variation in bud coloration along the longitudes. The points in the upper right (++) quadrant in figure 1 are seed sources from the eastern longitudes within the southeastern portion of the white spruce range; those in the lower right (+-)

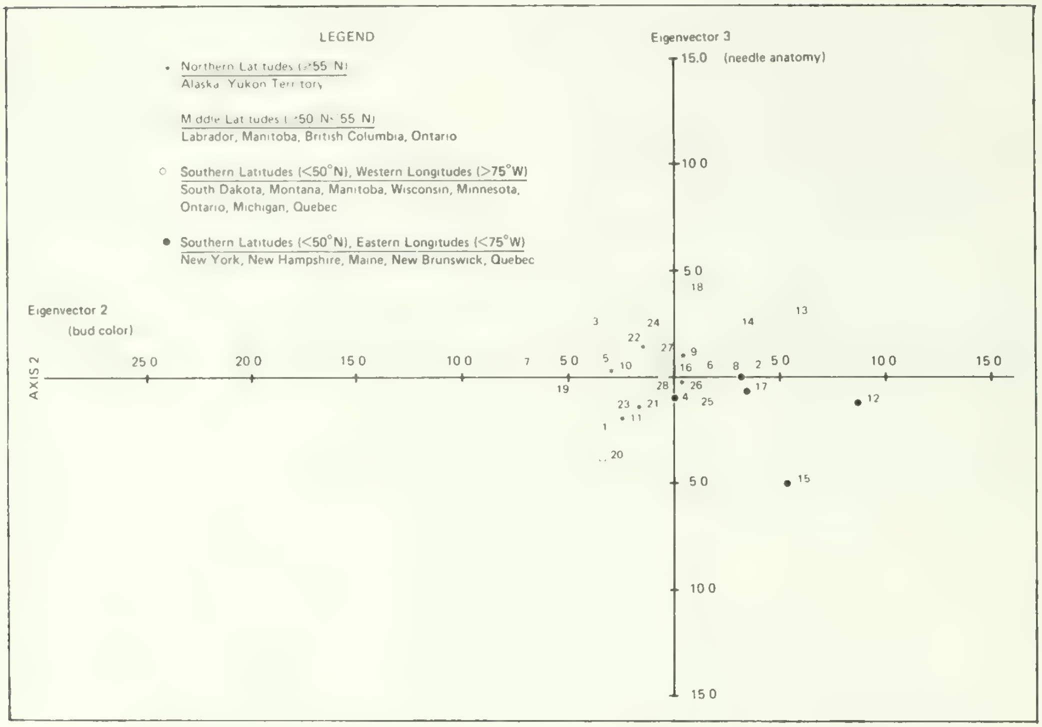

Figure 3.--*Ordination of white spruce provenances along eigenvectors 2 (bud color) and 3 (needle anatomy). This figure can be considered an "end view" of the ellipsoid.*

quadrant are from the western longitudes within this sub-group.

The third component--needle anatomy--in figure 2 or 3 provides little discrimination among points. This gives credence to the fact that few orthogonal variables were measured.

In a review of the systematics of white spruce, Nienstaedt and Teich (1971) cite evidence for the division of the species into eastern and western populations. Needle characteristics such as color and length were cited as major contributors to the east-west variation pattern. The fact that the present white spruce population has evolved from populations that survived both the Illinoian and Wisconsin glaciations in widely separated refugia is also given as supporting evidence. Studies of monterpenes in cortical samples (Wilkinson *et al.* 1971) and DNA content per cell (Miksche 1968) also support the contention of two distinct populations.

As recognized by Nienstaedt and Teich (1971) and supported by the results of our PCA, the demarcation of white spruce into two populations would appear to be an oversimplification; however, the phytochemical characters cited above were not included in this analysis and would no doubt add new dimensions of discrimination if included. In support of the hypothesis of separate populations, the response to the second component, bud coloration, did differ in the western and eastern seed sources. However, no east-west variation pattern is evident in the needle anatomy (specifically, the number of upper surface stomata), the third principal component.

The preliminary nature of the white spruce study and the stated objective of measuring a large number of variables to assess their value as selection indices presents an ideal situation for the application of PCA. A comparison between the results of our analyses and those based on

analysis of variance (table 4) by Nienstaedt and Teich (1971) illustrates the value of PCA. Their analysis of variance shows that all 19 characteristics except needle color and second flushing were significantly different among provenances at the 0.01 level (table 4); thus, the ANOVA does not provide insight into the underlying dimensions of variability, nor does it provide guidance for the selection of variables suitable for emphasis in further studies.

Table 4.--*Analysis of variance of 19 characteristics measured on nursery grown white spruce representing 28 provenances from the entire range of the species* 1/

Variable	F value
Height (in.)	15.61*
Diameter (mm)	30.75*
No. of branches	4.35*
Branch length	10.63*
Shape of bud	2.77*
Bud color	5.67*
Length of buds	15.95*
Needle length	5.40*
Cross section of needle	2.94*
Needle rigidity	2.55*
Needle color	n.s.
Needle curvature	2.42*
No. of stomata upper	2.72*
No. of stomata below	4.59*
Needle serrulation	6.08*
Branch surface	8.05*
Sterigmata length	4.68*
Secondary bud flushing	n.s.
Forking	3.78*

1/ From Nienstaedt and Teich (1971)
* Significant at the 1 percent level

It is noteworthy that the two nonsignificant variables in the ANOVA were identified by PCA as important orthogonal variables worthy of further consideration. Substantial variation is known to occur in these two characteristics. It is also possible that the strong interdependence of these variables resulted in a non-significant interpretation among provenances in the non-orthogonal ANOVA.

Principal component ordination is one of a multitude of ordination techniques, but is not necessarily the most effective. In the first comparison of principle component ordination to other techniques that numerically approximate multivariate analysis (e.g., Bray and Curtis 1957, Swan, Dix, and Wehrhahn 1969), PCA was found to be superior (Austin and Orloci 1966, Orloci 1966). But subsequent studies by other authors have obtained the contrary conclusion (Bannister 1968, Austin and Noy-Meir 1971, Gauch and Whittaker 1972, Whittaker and Gauch 1972, Gauch 1973).

It is evident from these evaluations that like any mathematical technique, ordination is most effective when the user is aware of the limitations as well as the capabilities of the particular technique (Gauch 1973). Ordination is a linear mapping technique and if the parameters under study respond to an experimental stimulus in a nonlinear fashion (i.e., a non-monotonic performance or response), the representation of the parameter/stimulus relation in a multidimensional space (ordination) may be distorted. For example, in the ecological sphere, the response of vegetation to environmental gradients is highly nonlinear. In such a case, if one does not recognize the discrepancy between the linear assumption of the ordination methods and the nonlinear response by the biological system, evaluation of vegetational patterns as influenced by environmental factors can lead to spurious conclusions.

Multiplotting

It is often desirable or necessary to visualize the results in as many dimensions as possible, but plotting of multivariate data is limited by human perception. To circumvent this problem, contouring or the addition of symbols can be used to extend the number of axes on a two-dimensional plot. However, such plots lack precision and soon become difficult to interpret with the additional clutter. Physical models or 3-D plots from stereo equipment can be used for interpretation of multivariate data, but n-dimensional data still cannot be perceived.

To solve this problem, Andrews (1972) suggested that one should map points into a function and then plot the function. A function can be infinite in its dimensions

and still be easily visualized in two-dimensional space. This allows interpretation in more than three dimensions. The function proposed by Andrews (1972) follows:

$$f_\zeta(t) = \zeta_1/\sqrt{2} + \zeta_2 \sin t + \zeta_3 \cos t + \zeta_4 \sin 2t + \zeta_5 \cos 2t$$

For each point the function is defined and then plotted over the range

$$-\pi < t < \pi \qquad \zeta_i = \sum_1^j x_{ij} a_{ij}$$

Thus a set of points is transformed into a set of lines that has many appealing properties.

For example, the functional mean corresponds to the mean of the observations themselves: that is, if $\bar{x}$ is the mean of n-multivariate observations, the function corresponding to $\bar{x}$ will appear as an average on the plots. Such a set of lines also preserves distances. If plotted functions are close together for all values of t, the corresponding points are close together in n-dimensional space and a band of functions represents a cluster of data points. If a group of functions are close together for only one value of t, the corresponding points are close in the direction defined by the corresponding projection in one-dimensional space. Therefore, even with n-dimensions groups of points can be identified.

This function also preserves variances. Therefore, tests of significance and confidence intervals can be constructed at particular values of t because the variance of $f_\zeta(t)$ is known.

The major advantage of multiplotting is not the establishment of variation patterns based on a single orthogonal character or even several characters, but the discrimination among populations based on the integral of characters. For example, Jeffers (1972) distinguishes a number of birch species by multiplotting five components of 13 leaf characters. In his example, several birch hybrids are evident from their intermediate position on the plots. In addition, Andrews (1972) demonstrates how biological data can be misinterpreted when only two-dimensional point plotting is used.

Principal Components in Conjunction With Regression Analysis

Many forest biologists often wish to build a model to predict a dependent variable (Y) from a complex set of interrelated independent variables (x's). When selecting their variables, they often are faced with a dilemma. They not only want to include the variables that are most influential in controlling the systems, but also enough variables to obtain a reasonable fit, so their models are useful for predictive purposes (Draper and Smith 1966). However, large numbers of variables increase the complexity of a model tremendously (Goodall 1972). Therefore, they may wish to choose a method of variable selection when building a preliminary model.

If adequate degrees of freedom are available, many would prefer to perform preliminary analysis and model building on one-half of the data and then test the model on the other half to validate the model. However, others feel that this is unnecessary in preliminary experiments because data will be gathered subsequently to test the model and to update it. We chose the latter approach in the following example.

Many methods are now available for selecting variables to use in a regression equation: these include the all regressions approach, backward elimination, forward selection, stepwise regression, and several combined techniques. Several of these methods do not give satisfactory results when the intercorrelation between the x's is high (Draper and Smith 1966). This is because under conditions of normality, the higher the correlations between variables, the less orthogonal the data will be (Draper and Smith 1969). Furthermore, the selection methods don't necessarily help us select the best equation; but usually they will allow us to find an acceptable one.

Another problem that must be considered is that some of these methods require repeated tests of significance; therefore, they are based on conditional decisions (i.e., one test

influenced by the previous test). In this case, one may be operating at a different probability level than expected. Little consideration usually is given to the consequences of such conditional tests (Kennedy and Bancroft 1971).

Principal component analysis also can be used in conjunction with multiple regression to select variables for a regression equation. Various approaches have been reported by Kendall (1957), Ahamad (1967), Beale *et al.* (1967), Jeffers (1967), Spurrell (1963), Cox (1968), and Decourt *et al.* (1969).

Kendall used the standard multiple regression model:

$$Y = b_o + b_1 \zeta_1 + b_2 \zeta_2 + \ldots + b_p \zeta_p + \varepsilon \quad (1)$$

in which he substituted ζ_i's for x's where ζ_i = i^{th} principal component from the set of variables.

By applying the principle of least squares, the estimates of the b's are obtained by solving the set of normal equations. In this case the coefficients

$$b_i = \frac{\Sigma y \zeta_i}{\Sigma \zeta_i^2} \quad (2)$$

as in orthogonal polynomials (Anderson and Houseman 1942). Furthermore, the reduction due to fitting the regression on the ζ_i's is $b_i \; \Sigma y \zeta_i$, which is also equal to $\lambda_i b_i^2$. Solving this equality for b_i, we obtain

$$b_i = \frac{\Sigma y \zeta_i}{\lambda_i} \quad (3)$$

which can be used in evaluating the contribution of the original variables as follows.

In Kendall's procedure, PCA is run on the correlation matrix of the original set of variables. Then the b_i's are found by solving equation (3). When solving for b_1, each eigenvector coefficient in eigenvector 1 is multiplied by the correlation coefficient of that x and Y and then summed for the eigenvector. This value is then divided by its eigenvalue (λ_i) (i.e., $b_1 = \frac{\Sigma y \zeta_1}{\lambda_1}$).

All eigenvectors having eigenvalues near zero are neglected because they contribute little to the total variance. The total variance is calculated for each b_i by solving

$$\sigma^2_{b_i} = \lambda_i b_i^2 \quad (4)$$

To evaluate the contribution of the x's, Kendall substituted the b_i's and the ζ_i's in terms of standardized x's into the original equation (1), which produced an equation of coefficients and standardized x's. The b_i's reflect both the sign and sizes of each x variable's contribution.

This approach is most useful when the number of variables is small. However, the problem with this approach is that when the number of variables is large it is often difficult to interpret the results in terms of the individual variables that are embedded in the linear combination (eigenvectors). There also is often some question as to whether the dimension of the problem is truly reduced because the components have contributions from all the x's. Therefore, we believe this approach should be used only when the experimenter can assign biological meaning to certain significant components (eigenvectors), or when the number of variables is small.

Cox (1968) advocated the use of PCA in preliminary experiments to suggest regressor variables. In his method the principal components themselves are not used in the regression equation as in Kendall's procedure. Rather, Cox used simple combinations of variables having physical meaning. We have chosen Cox's approach to illustrate our second example.

In this example we have used the data of Larson (1967). He measured 12 growth variables on trees from 10 red pine seed sources

grown under various conditions in controlled growth rooms (table 5).

After a Bartlett's test indicated that the data had homogeneity of variance, multiple regression analysis was run of the 10 independent variables upon volume increment. The ANOV table for regression is shown in table 6. Note the regression was significant and the R^2 = 0.98. It should be emphasized, however, that Larson (1967) did not relate his variables to volume increment as we have done, nor did he suggest this relationship. Rather, we have arbitrarily picked volume increment as the dependent variable for purposes of illustration.

Table 5.--*Selected tree growth measurements and first four eigenvectors of principal component analysis from 10 red pine provenances grown in growth rooms* 1/

List of variables		Eigenvectors (A_i)			
		1	2	3	4
x_1	Height (cm)	0.351	-0.031	-0.381	-0.163
x_2	Needle length, 1962 (cm)	-0.310	-0.111	0.370	0.576
x_3	Needle weight, 1962 (gm)	0.382	-0.020	0.045	-0.112
x_4	Needle weight, 1961 (gm)	0.384	0.040	0.065	-0.239
x_5	Total ring width (mm)	0.319	0.368	0.250	0.254
x_6	Earlywood width (mm)	0.371	0.053	0.268	0.213
x_7	Latewood width (mm)	0.124	0.711	0.054	0.145
x_8	Latewood percent (%)	-0.275	0.501	-0.234	-0.063
x_9	Specific gravity	-0.343	0.281	-0.263	-0.137
x_{10}	Cell wall thickness (μ)	0.199	-0.111	-0.671	0.647
Y_1	Volume increment (mm^3)				

1/ Adapted from Larson (1967); in the original study, the author made no attempt to relate the independent variables listed to volume increment.

Table 6.--*ANOV for regression of 10 selected red pine growth measurements (x's) on volume increment (Y) (R^2=0.98)*

Source	df	S.S.	M.S.	F
Regression	10	1977630.25	197763.03	69.37*
Deviations	29	82673.52	2850.81	
TOTAL	39	2060303.77		

* Denotes significance at the 0.01 probability level.

Next, a principal component analysis was run on the 10 x 10 correlation matrix of the independent variables (x's). The 10 eigenvalues (λ's) and the cummulative percentage of the total variation associated with each are shown in table 7. Kendall (1957) has shown that when collinearities exist in the x's (i.e., some λ's near zero) no reliance can be put on the individual coefficients in regression equations which include all the variables. Note that collinearities exist in our example since eigenvalues 5 through 10 are near zero (table 7). Consequently, for each eigenvalue near zero, one variable can be expressed in terms of the other variables, and, therefore, the number of variables can be reduced (Kendall 1957, Seal 1964).

Table 7.--*Eigenvalues and cumulative percentage of variation associated with the eigenvalues from principal component analysis of red pine provenance grown in the growth room*

Eigenvalues		Cumulative percent of variation
1.	6.45	0.645
2.	1.75	0.820
3.	1.11	0.932
4.	0.53	0.984
5.	0.09	0.993
6.	0.04	0.998
7.	0.02	0.999
8.	0.00	1.000
9.	0.00	1.000
10.	0.00	1.000

Selection of the variables to retain for regression is done in the same manner as in our white spruce example, that is, choosing the variables having the largest coefficient absolute value in the most significant eigenvectors.

Several regression equations may be picked using this method which on the surface may appear to be very different. However, for predictive purposes the equations often are equally effective (i.e., have a large R^2 and a good fit) (Kendall 1957).

In our PCA run it seemed likely that at least six or seven variables might be eliminated from the analysis and still have a regression equation that "explained" a large portion of the total sums of squares. Six of the eigenvalues were near zero (eigenvalue 5 through 10) (table 7); therefore, these 6 variables were no doubt interrelated with 4 or 5 more important variables.

The first four eigenvectors and their respective coefficients are shown in table 5. When λ_0 is chosen equal to 1.0, as in the white spruce example, these four eigenvectors "explain" 98.4 percent of the total variation in the independent variables; similarly, the first three eigenvectors "explain" 93.2 percent of the variation (table 7).

The first eigenvector from table 5 "explained" 64.5 percent of the total variation in the independent variables (x's). It has two coefficients that qualify for the largest absolute value because they are approximately the same equal magnitude, needle weight, 1962 (x_3), and needle weight, 1961 (x_4) (circled in table 5). Similarly, in eigenvector 2, the coefficient having the largest absolute value is latewood width (x_7). In both eigenvectors 3 and 4, the largest coefficient is cell wall thickness (x_{10}).

When one encounters a variable in an eigenvector with a coefficient of largest absolute value that has already been associated with a previous eigenvector, then the next largest coefficient in the eigenvector is chosen. Therefore, in eigenvector 4, inasmuch as cell wall thickness is already associated with eigenvector 3, the next largest coefficient in eigenvector 4 is needle length (x_2); therefore, needle length is chosen.

The five variables chosen from the first 4 eigenvectors are the ones to consider for regression analysis. The ANOV for regression of these five variables on volume increment is shown in table 8. The regression was significant and that R^2 = 0.92, and examination of the residuals indicates a good fit. This indicated that 5 independent variables "explained" nearly as much of the total variation in volume increment as did all 10 independent variables (table 6).

The examination of eigenvectors in search for the largest coefficient must be done with caution especially when two variables have a correlation coefficient (r)

Table 8.--*ANOV for regression of needle length, needle weight (1962), needle weight (1961), latewood width, and cell wall thickness on volume increment (Y) (R^2=0.92)*

Source	df	S.S.	M.S.	F
Regression	5	1902309.43	380461.89	81.9*
Deviations	34	157996.60	4646.95	
TOTAL	29	2060306.03		

* Denotes significance at the 0.01 probability level.

near ± 1. When this occurs, scientific insight must be often used in favor of a set of mathematical techniques.

For example, in our case, needle weight for 1962 and needle weight for 1961 are highly correlated (near ± 1); therefore, only one need be included in the analysis.

Because cell wall thickness is difficult and expensive to measure and is associated with the third and fourth eigenvectors, one might be tempted to look at a regression of needle weight, latewood width, and needle length on volume increment and leave out cell wall thickness. Table 10 shows the ANOV for this regression. The regression was significant and R^2 = 0.90. It appears that the variables chosen

Table 9.--*ANOV for regression of needle length, needle weight (1962), latewood width and cell wall thickness on volume increment (Y) (R^2=0.91)*

Source	df	S.S.	M.S.	F
Regression	4	1868894.50	467223.62	85.4*
Deviations	35	191411.53	5468.90	
TOTAL	39	2060306.03		

* Denotes significance at the 0.01 probability level.

Needle weight for 1962 was retained because of ease of measurement and needle weight for 1961 was dropped. The ANOV for regression of the four other variables is shown in table 9. By dropping the variable needle weight for 1961, the R^2 was reduced from 0.92 to 0.91; therefore, little was lost. Examination of the residuals also indicated a good fit.

by this analysis "explain" a high portion of the regression sums of squares for volume increment. Although needle weight, needle length, and latewood width have some indirect biological integrity as predictors of volume, the main purpose for including this example was to illustrate the various aspects of variable selection that an experimenter may use for further experimentation.

Table 10.--*ANOV for regression of needle length, needle weight (1962), and latewood width on volume increment (Y) (R^2=0.90)*

Source	df	S.S.	M.S.	F
Regression	3	1859829.03	619943.01	111.3*
Deviations	36	200477.00	5568.80	
TOTAL	39	2060306.03		

* Denotes significance at the 0.01 probability level.

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AMERICAN REVOLUTION BICENTENNIAL
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SDA FOREST SERVICE
ENERAL TECHNICAL REPORT NC-18

the forest roducts industry and the environment: a selected bibliography

ompiled by:

Jerry A. Sesco

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Aesthetics: 274, 313, 370, 408
Air Pollution: 3, 4, 30, 36, 38, 42, 58, 63, 64, 94, 95, 97, 108, 109, 113, 114, 124, 127, 138, 139, 140, 142, 149, 156, 157, 162, 180, 185, 187, 191, 203, 206, 212, 233, 244, 269, 271, 284, 288, 289, 308, 317, 337, 339, 346, 356, 361, 393, 438, 440, 454, 458, 462, 464, 476, 479, 480, 481, 482, 491
Bark: 88, 97, 140, 167, 200, 224, 267, 311, 379, 403, 487
Burning: 36, 37, 38, 64, 89, 94, 95, 97, 100, 113, 139, 142, 147, 154, 155, 159, 162, 289, 308, 338, 339, 407, 410, 415, 478, 492
Clearcutting: 6, 15, 20, 41, 43, 44, 52, 53, 54, 81, 106, 107, 112, 173, 183, 184, 196, 199, 222, 238, 252, 256, 257, 275, 276, 283, 312, 326, 327, 329, 334, 351, 362, 375, 381, 395, 399, 406, 425, 426, 428, 429, 434, 444, 445, 449, 473
Compositing: 24
Controlled Burning: 162, 289, 337
Dominant Use: 312
Earth Day 1970: 282
Economic Impact: 66, 90, 110, 118, 131, 143, 163, 304, 342, 357, 380
Economics of Pollution: 27, 151
Energy Crisis: 220, 296
Energy Needs: 116
Energy Requirements: 144, 189, 190, 296, 423, 424, 485
Energy Source: 37, 200, 203, 285
Environmental Aspects of Forests: 23, 65, 67, 73, 76, 122, 130, 171, 204, 217, 219, 242, 246, 253, 274, 290, 335, 349, 356, 358, 384, 386, 400, 423, 424, 452, 467, 470, 493
Environmental Aspects of Wood: 61, 76, 79, 98, 104, 135, 152, 189, 190, 213, 290, 296, 366, 367, 368, 423, 424, 485, 493
Environmental Forestry: 23, 62, 91, 102, 277, 278, 279, 347, 353
Environmental Impact: 12, 13, 104, 125, 179, 250, 254, 269, 271, 304, 336, 342, 350, 357, 380, 392, 451, 452
Environmental Information: 7, 103, 123, 146, 205, 238, 324, 338, 391, 433, 448, 460, 461, 462
Environmental Movement: 34, 62, 82, 91, 111, 143, 153, 170, 178, 197, 213, 214, 218, 221, 243, 254, 255, 262, 285, 300, 322, 330, 345, 348, 354, 364, 365, 371, 374, 380, 389, 404, 405, 437, 452, 465, 469, 494
Environmental Protection: 29, 31, 60, 71, 74, 80, 165, 211, 268, 270, 313, 392, 432, 483
Erosion: 158, 173, 230, 272, 273, 355
Even-Aged Management: 106
Falcon: 188
Fertilizer Use: 16, 176, 198, 249, 350, 456, 463
Foreign Trade: 194
Forest Chemicals: 310
Forest Fire Pollution: 22, 487
Forest Fuel Accumulation: 115, 180, 471, 472
Forest Industry Lands: 306
Forest Management: 23, 160
Forest Policy: 56
Forest Recreation: 340, 384
Forest Use: 70
Forestry Programs: 62, 398
Furniture Industry: 488
Glue Waste Disposal: 161, 186, 487
Hardboard Pollution: 233, 420, 487
Harvesting Methods: 77
Harvesting Pollution: 6, 15, 43, 45, 47, 50, 51, 52, 53, 54, 77, 117, 126, 158, 173, 183, 184, 199, 228, 247, 251, 256, 257, 272, 293, 316, 318, 319, 323, 324, 334, 355, 362, 363, 375, 408, 410, 411, 441, 442, 443, 449
Helicopter Logging: 57
Herbicide Use: 239, 240, 309, 413, 414
Land-Use Planning: 11, 68, 78, 177, 208, 457, 468
Land-Use Restrictions: 209, 250, 281
Log Transport and Storage: 117, 192, 320, 373, 402, 403
Logging Residues: 69, 80, 94, 95, 112, 113, 159, 202, 308, 450
Multiple Use: 11, 177, 312, 330
National Forests: 71, 275, 305, 307, 341, 344, 378, 427, 435, 484
Natural Areas: 287
Noise Pollution: 1, 28, 33, 83, 84, 148, 175, 206, 225, 226, 227, 234, 235, 236, 258, 260, 261, 269, 271, 292, 359, 391, 446, 453, 475, 489, 490
Non-Timber Values: 211, 285
Nutrient Budget: 239, 240, 256, 257, 329, 429
Odor Pollution: 138, 284
Paper Industry: 5, 9, 32, 66, 90, 241, 264, 321, 345, 361, 376, 460, 461, 462, 491
Particleboard Pollution: 108, 117, 259, 420, 487
Pesticide Use: 168, 193, 207, 332, 414
Pinchot Institute: 333
Plywood Pollution: 35, 42, 117, 237, 303, 346, 420, 454, 466
Pollution Legislation: 30, 58, 92, 93, 109, 205, 214, 281, 383, 402

Prescribed Burning: 85, 86, 99, 114, 180, 288, 289, 360, 390, 431
Preservation: 14, 221, 287
Private Woodlands: 385, 398, 419
Recycling: 8, 17, 18, 105, 129, 150, 181, 291, 294, 343, 382, 421
Research: 133, 134, 353, 366, 367, 471
Residue: 19, 39, 88, 164, 195, 263, 325, 372, 377, 412, 433, 459, 466
Road Construction: 158, 166, 230, 273, 334, 336, 410
Sawmill Pollution: 35, 117, 165, 420, 486, 487
Sediment: 52, 54, 158, 173, 230, 272, 273, 328
Skyline Logging: 247
Social Aspects of Forests: 384
Soil Depletion: 256, 257
Tepee Burners: 87, 88, 155, 317, 478, 479, 480, 492
Thermal Pollution: 43, 46, 47, 49, 53, 55, 229, 324, 411
Timber Availability: 305
Timber Demand: 75, 80, 218, 266, 298, 342
Timber Management: 25, 68, 72, 106, 107, 119, 120, 126, 136, 145, 169, 182, 218, 254, 278, 281, 299, 319, 359, 383, 387, 394, 399, 409, 419, 422, 427, 428, 429, 430, 432, 434, 435, 441, 455, 468, 469
Timber Sales: 341
Timber Supply: 14, 59, 74, 75, 105, 174, 179, 231, 232, 265, 266, 285, 286, 295, 297, 298, 301, 302, 304, 306, 307, 342, 352, 357, 388, 412, 436, 439, 447, 451, 484
Urban Environment: 130, 171, 182, 242, 286, 314, 335, 353, 354, 356, 358, 364, 393, 396, 495
Urban Forestry: 353, 358, 419, 495
Urban Wastes: 18, 331
Visual Pollution: 119, 182, 201, 216, 251, 252, 401, 409
Waste Burners: 36, 37, 38, 64, 97, 100, 139, 140, 142, 149, 155, 317, 415, 478, 479, 480
Waste Disposal: 19, 35, 36, 88, 89, 94, 95, 97, 101, 113, 140, 147, 149, 154, 156, 224, 245, 308, 338, 396, 401, 450, 466, 470, 492
Waste Utilization: 10, 18, 19, 24, 39, 40, 69, 167, 195, 200, 203, 245, 248, 263, 267, 311, 325, 331, 372, 377, 412, 433, 436, 459, 466, 477, 479
Water Pollution: 2, 15, 16, 21, 25, 26, 35, 40, 45, 48, 50, 51, 54, 96, 101, 121, 132, 141, 145, 159, 160, 161, 172, 184, 186, 192, 199, 206, 210, 223, 230, 241, 249, 264, 269, 271, 273, 293, 303, 310, 320, 323, 334, 350, 362, 363, 373, 379, 397, 403, 408, 411, 416, 417, 418, 442, 446, 449, 460, 461, 463
Wild Lands: 315
Wilderness: 378
Wildlife: 196, 222, 326, 332, 351, 384, 455
Wood Preserving: 2, 21, 26, 121, 132, 210, 280, 416, 417, 418, 459
Wood Substitutes: 79, 98, 104, 144, 189, 190, 213, 368, 423, 424
Wood Utilization: 17, 128, 129, 134, 137, 144, 215, 231, 232, 302, 369, 436, 474

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AMERICAN REVOLUTION BICENTENNIAL 1776-1976

A FOREST SERVICE
ERAL TECHNICAL REPORT NC-19

a case study showing potential supplies of red pine wtimber

thomas c. marcin
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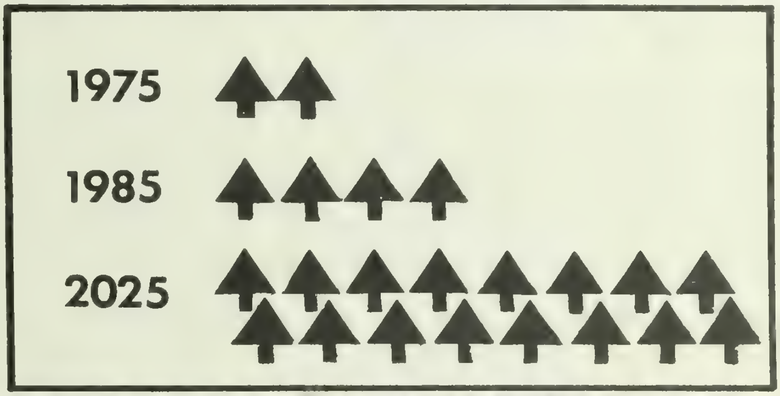

NORTH CENTRAL FOREST EXPERIMENT STATION
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CONTENTS

Present Situation on the Chippewa National Forest 2

Methods 2

Management Alternatives 4

Results 7

Conclusion. 7

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1975

A CASE STUDY SHOWING POTENTIAL SUPPLIES OF RED PINE SAWTIMBER IN THE LAKE STATES

Thomas C. Marcin and Darrell M. Frogness

Supplies of red pine sawtimber could icrease twentyfold throughout the Lake ates during the next 50 years. In Michin, more than 500,000 out of 600,000 acres red pine type were less than 40 years d in 1966. In Wisconsin, 85 percent of e 310,000 acres of red pine were less an 40 years old in 1968. In Minnesota, ly 87,000 acres of 284,000 acres of red ne were less than 40 years old in 1962. wever, 40,000 acres of red pine type were anted on the two national forests alone Minnesota between 1962 and 1972, which dicates that substantial areas of new d pine stands now are growing in the ate.

The potential long-term sawtimber oduction from Lake States red pine could at least 500 MMfbm (million board feet) year if these young stands are managed ing proper thinning schedules. Total nual cuts of red pine for the three ates presently range between 25 to 30 fbm. Although such an increase might t be significant nationally, it certainly uld be regionally.

Therefore, long-range planning to sure maximum development of this timber source in the future is needed now using mputerized methods already available. e of these is Timber RAM, which is a thod for choosing an optional schedule management treatments (Navon 1971).[1]

[1]*Daniel I. Navon. Timber RAM--a long-nge planning method for commercial timber nds under multiple-use management. USDA r. Serv. Res. Pap. PSW-70, 22 p., illus. c. Southwest For. and Range Exp. Stn., rkeley, Calif. 1971.*

Using Timber RAM the land manager can develop information needed for making decisions that are responsive to changing conditions. For example, if another shortage of softwood timber develops when housing construction rebounds, he could readily examine the long-term effects of an immediate short-term increase in timber cut.

The purpose of this report is to illustrate how Timber RAM was used to determine the potential timber supply of red pine sawtimber available on the Chippewa National Forest in northern Minnesota for the next 50 years at the three levels of management shown below.

Alternative 1--Low-intensity management.

1. Maintain old-aged stands.
2. Convert 11,200 acres to red pine in the next decade to maintain a base of 66,300 acres in red pine.
3. Cut 41 MMfbm of red pine in decade 1.

Alternative 2--Medium-intensity management.

1. Cut some old-aged stands in decade 1.
2. Convert 11,200 acres to red pine in decade 1; 10,000 acres in decades 2 and 3 to maintain a base of 86,300 acres of red pine.
3. Cut 60 MMfbm of red pine in decade 1.

Alternative 3--High-intensity management.

1. Cut old-aged stands in decade 1 and decade 2.
2. Convert 15,000 acres to red pine in decade 1, decade 2, and decade 3 to

maintain a base of 101,100 acres of red pine.

3. Cut 88 MMfbm of red pine in decade 1.

PRESENT SITUATION ON THE CHIPPEWA NATIONAL FOREST

In the 1970 inventory, 55,113 acres (10 percent) of the regulated commercial forest lands on the Chippewa National Forest were classified as red pine type. Of these, approximately 25 percent were in stands less than 10 years old (fig. 1).

This can be attributed to a planting program that has been in operation since the late 1940's, which produced increases in the red pine type of almost 10,000 acres between 1948 and 1960 and of an additional 13,000 acres between 1960 and 1970. This program is expected to continue: an additional 11,200 acres are expected to be planted between 1970 and 1980 and 10,000 acres in the 1980's and in the 1990's. As a result, growing stock, which increased from 47.5 $MMft^3$ in 1960 to 70 $MMft^3$ in 1970, is expected to continue to increase as the new plantations and second-growth natural stands mature.

In 1970, the volume of red pine within the red pine type only was estimated to be 275 Mfbm and the total volume of red pine in all timber types to be 354 Mfbm. Between fiscal years 1964-1973, timber sales of red pine and some white pine averaged 4,454 Mfbm annually while annual cut averaged 4,145 Mfbm. In the same period the average sale price doubled--from $26.01 to $52.91/Mfbm.

Even though the aspen type currently covers 37 percent of the commercial forest lands, red and white pine sawtimber provide the greatest single source of stumpage revenue. In fiscal year 1973, revenues from red and white pine sawtimber were $290,107 as compared with $100,000 from aspen.

METHODS

In our projections, we didn't attempt to delete the red pine type growing in travel and water influence zones because inventory data were only available on a forest-wide basis. Furthermore, the acreage of red pine type growing in such zones is so small that it wouldn't significantly affect our projections.

The area of red pine type was subdivided into the 10 age classes, 2 site classes, and 3 stocking classes shown in table 1. Twenty-nine timber classes were defined from these site-stocking-age combinations. For these timber classes, average stand condition was estimated for projection of volume yields. These conditions are summarized in table 2, in which a three-letter code is assigned for the Timber RAM program.

To project volume yields for each timber class, a set of management activities must be specified for the RAM program. We assumed that the red pine stands would be thinned every 10 years to 90 ft^2 of basal area. In addition the RAM special-activity option was used for the 902 acres of mature medium-stocked red pine type scheduled to be harvested during decade 1 (1972-1982). We added the estimated volume of red pine from other types to the harvest volume from these 902 acres in our projections for this first decade.

We projected red pine yields using a computerized stand growth simulator[2] developed by Lundgren. This model is based on growth analyses of data from the Chippewa National Forest by Wambach (1967)[3] and Buckman (1962).[4]

Yields for future plantations were estimated using alternative levels of initial plantings ranging from 400 to 1,200 trees/acre and of thinnings to residual stands varying from 60 to 120 ft^2 of basal area. We found that an average of 600 surviving trees/acre thinned to a residual of 90 ft^2 of basal area approximated maximum growth for a wide variety of conditions. We reduced the yields projected by the model to 20 percent because the model only accounts for tree mortality caused by crowding (i.e., excessive density).

---

[2]*This model is called REDPINE. It was developed by Dr. A. L. Lundgren, Principal Economist, North Central Forest Experiment Station, St. Paul, Minnesota.*

[3]*Robert F. Wambach. A silvicultural and economic appraisal of initial spacing in red pine. Ph.D. dissertation available from University Microfilms, Inc., Ann Arbor, Mich. 282 p. 1967.*

[4]*Robert E. Buckman. Growth and yield of red pine in Minnesota. USDA For. Serv. Tech. Bull. 1272, 50 p. North Cent. For. Exp. Stn., St. Paul, Minn. 1962.*

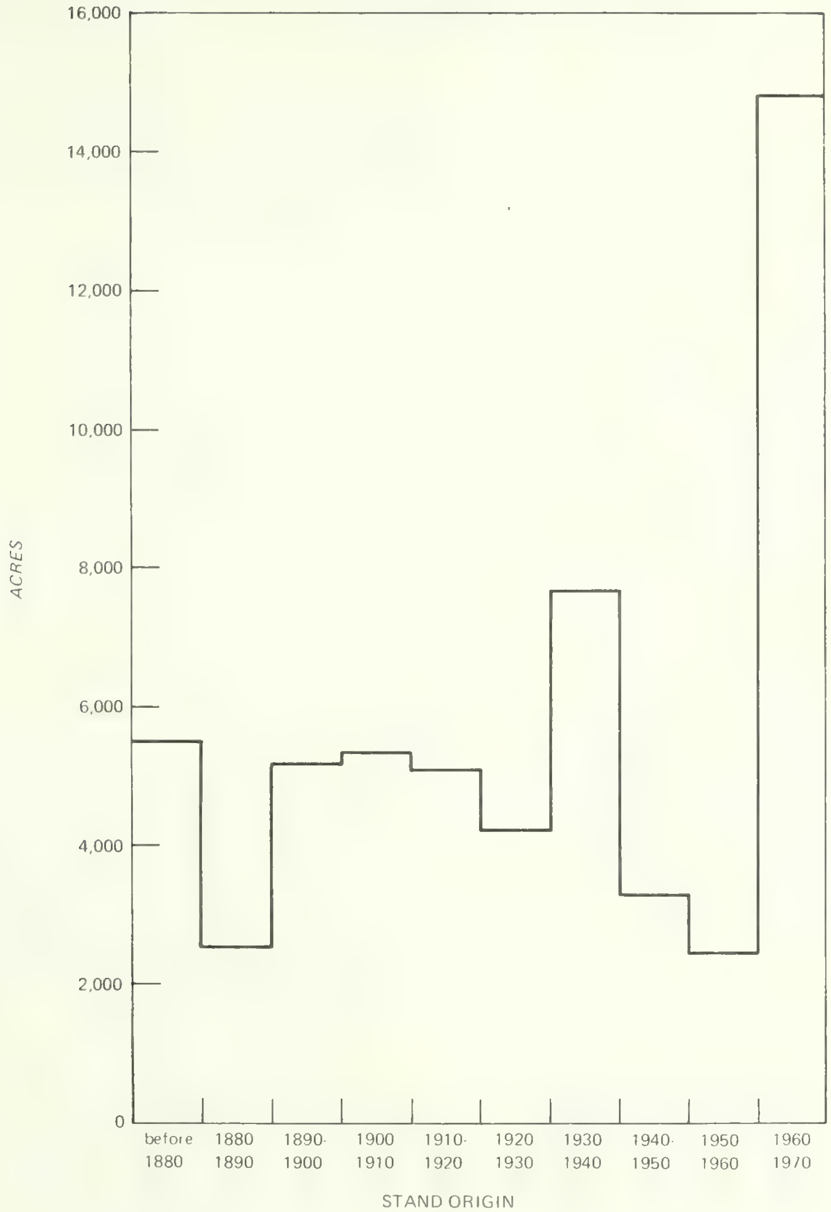


Figure 1.--*Area of red pine type by year of origin, Chippewa National Forest, 1970.*

Table 1.--*Chippewa National Forest 1970 inventory area for red pine type by age, stocking, and site index*

(In acres)

Age	Stocking						Total
	Poor[1]	Medium[2]	Good[3]	Poor[1]	Medium[2]	Good[3]	
	Site index ≤ 65			Site index > 65			
90+		902	4,633				5,535
80-89		478	1,800				2,278
70-79	159		5,021				5,180
60-69		683	2,899			1,263	5,345
50-59	601	891	2,827	151	604		5,074
40-49	326	777	3,108				4,211
30-39			3,843		879	2,946	7,668
20-29		600	2,075		571		3,246
10-19		1,059	792			567	2,418
0- 9		1,366	7,258			6,034	14,658
Total	1,086	6,756	34,256	151	2,054	10,810	55,113

[1]Basal area range < 40 ft.
[2]Basal area ≥ 40 ft^2 to < 80 ft^2.
[3]Basal area ≥ 80 ft^2.

Yield information is entered into the RAM program by means of volume yield tables. Therefore, for simplicity, we limited our input to the six model stands shown in table 3. These stands characterize those found on the Chippewa National Forest.

MANAGEMENT ALTERNATIVES

Because of its stable growth characteristics, red pine can be managed for a wide range of stand conditions and stand ages. Although rotation ages of 80 to 100 years often are recommended for sawtimber production from red pine plantations, red pine stands still continue to grow well up to, or beyond, 150 years. Thus, there are many acceptable management regimes for red pine.

However, our three alternatives were based on the following assumptions. Beginning at about age 30, red pine stands would be thinned every 10 years to 90 ft^2 of basal area and would be allowed to reach 150 years of age. New plantations would average 600 surviving trees/acre and would be managed on a 90-year rotation. At age 90, stands managed under this regime will average 17 in. d.b.h. for site index 55 and 23 in. d.b.h. for site index 70.

However, larger trees could be produced at lower densities if stands were managed at lower densities. For example thinning to 60 ft^2 of basal area on site index 55 would yield trees of 20 in. d.b.h. at age 90. Because volume control based on intermediate and harvest cuts is used for managing existing stands, the rotation age assumption only indirectly affects their management.

However, harvest levels can be constrained using either area or volume control. In general, however, some amount of constraint by area is desirable to achieve a balanced age-class distribution of forest types for diverse wildlife habitat and to maintain a sustained orderly flow of timber from the forest. National forests in the Lake States have been managed using area control to produce a regulated, balanced distribution of age classes after one rotation.

We used volume control because it enabled us to limit the fluctuation of harvest volumes between decades based upon future volume estimates of timber from intermediate and harvest cuts.

Each of our alternatives offers an increasing level of future harvest having the long-range sustained average cuts shown in

igure 2. The projected long-range sustained ield averages per decade are 293 MMfbm for alternative 1, 386 MMfbm for alternative 2, and 450 MMfbm for alternative 3.

Table 2.--*Timber class characteristics and estimated stand conditions used to estimate red pine yields on the Chippewa National Forest*

RAM Timber class code	Timber class characteristics			Average stand conditions	
	Average age in 1975	Average site index	Stocking class[1]	Basal area	Trees/acre
				Ft²	*Number*
RAA	110	55	Good	100	120
RAB	110	55	Medium	60	70
R9A	90	55	Good	100	150
R9B	90	55	Medium	60	90
R8A	80	55	Good	100	170
R8C	80	55	Poor	30	50
R7A	70	55	Good	100	220
R7B	70	55	Medium	60	130
R7D	70	70	Good	100	140
R6A	60	55	Good	100	270
R6B	60	55	Medium	60	160
R6C	60	55	Poor	30	80
R6E	60	70	Medium	60	100
R6F	60	70	Poor	30	50
R5A	50	55	Good	100	370
R5B	50	55	Medium	60	220
R5C	50	55	Poor	30	110
R4A	40	55	Good	100	600
R4D	40	70	Good	100	350
R4E	40	70	Medium	60	210
R3A[2]	30	55	Good		
R3B[2]	30	55	Medium		
R3E[2]	30	70	Medium		
R2A[2]	20	55	Good		
R2B[2]	20	55	Medium		
R2D[2]	20	70	Good		
R1A[2]	10	55	Good		
R1B[2]	10	55	Medium		
R1D[2]	10	70	Good		

[1]Good $\geq$ 80 ft^2 of residual basal area; medium $\geq$ 40 ft^2 to < 80 ft^2; and poor < 40 ft^2.

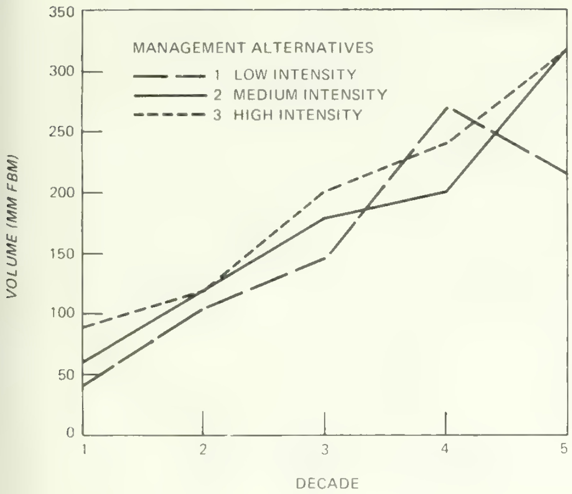
[2]These were assumed to be plantation stands having an average of 600 trees/acre. (For stands 30 years or younger, basal area is not considered important.)

Table 3.--*Red pine volume yields with 20 percent reduction for model stands thinned every 10 years to 90 ft² of basal area*

(In thousand board feet)[1]

Age	Volume before thinning	Thinning volume
WELL-STOCKED, SITE INDEX 55, OLD-AGED STANDS		
110	17.0	1.7
120	20.5	3.6
130	21.7	3.3
140	22.7	3.3
150	23.7	3.1
POORLY STOCKED, SITE INDEX 55, MIDDLE-AGED STANDS		
80	3.3	0
90	6.2	0
100	10.0	0
110	14.2	0
120	18.5	1.7
130	21.0	3.2
140	21.5	3.1
150	21.8	
WELL-STOCKED, SITE INDEX 55, MIDDLE-AGED STANDS		
60	3.0	1.0
70	9.1	2.6
80	14.4	3.9
90	16.5	3.9
100	18.5	4.0
110	19.3	3.6
120	20.3	3.5
130	20.8	3.1
140	21.4	3.1
150	21.7	
WELL-STOCKED, SITE INDEX 70, MIDDLE-AGED STANDS		
70	12.7	1.3
80	21.1	6.7
90	24.1	7.3
100	26.0	7.1
110	27.8	7.1
120	29.1	6.7
130	30.4	6.0
140	30.3	5.5
150	29.9	
WELL-STOCKED, SITE INDEX 55, PLANTATION		
40	0	0
50	3.7	1.3
60	10.7	3.4
70	15.1	4.4
80	17.6	4.7
90	19.3	4.6
100	20.6	4.5
110	21.4	4.0
120	22.1	3.9
130	22.6	3.4
140	22.8	3.3
150	22.7	
WELL-STOCKED, SITE INDEX 70, PLANTATION		
40	3.8	1.6
50	14.7	5.8
60	20.2	7.4
70	24.1	8.3
80	26.2	8.1
90	27.3	7.1
100	28.8	6.7
110	28.7	5.6
120	28.2	5.0
130	29.0	4.6
140	29.0	4.2
150	29.0	

[1]International ¼-inch rule.



:gure 2.--*Projections of total sawtimber volume cut from the Chippewa National Forest per decade for three management alternatives.*

RESULTS

Under alternative 1, total harvest lume could increase to over 200 MMfbm, most all of which would be derived from innings (table 4). This is based on an nual cut of about 41 MMfbm for the period 64-1973. Under alternative 2 total harvest lume could be increased from 60 MMfbm in e next decade to over 300 MMfbm in decade most of which would also be derived from innings for alternative 2 level management. der alternative 3, 88.3 MMfbm could be t in decade 1 if harvest cuts could be celerated.

To approximate large and small saw log ze material, we divided total saw log lume into: (a) cuts from stands under 80 ırs old, and (b) cuts from stands 80 years l older. All three alternatives will pro- le an increasing supply of saw logs from ınds 80 years and older as shown in ;ure 3.

The average ages at which harvest or eneration cuts would be made are shown table 5. All would be over 100 years the 5 decades even under management ernative 3. Under alternative 2, a relatively uniform area of regeneration cuts in existing stands could be maintained until younger plantations reach maturity. Furthermore, the average age at harvest would be increased to over 130 years after the second decade. It would decrease during the fifth decade.

Under alternative 1, stands would be maintained until they are 150 years old and the existing 4,633 acres of old-age stands would be cut in the fourth decade. Only 90 acres a year would be harvest cut and regenerated during the first decade; none during the following two decades.

At the other extreme, alternative 3 cutting of existing stands would be accelerated; harvest cuts varying from 1,546 acres in the second decade to 9,334 acres in decade 5 would be scheduled. Existing stands would be harvested as soon as younger plantations are available, which would forestall a fall off in total volume cut.

Under alternative 2, harvest cuts would range from about 1,200 acres in decade 2 to nearly 2,400 acres in decade 4 and 6,224 acres are scheduled for cut as younger stands reach maturity in decade 5.

CONCLUSION

The present allowable cut for the Chippewa National Forest could be doubled in the next decade to 8.8 MMfbm a year while maintaining a steady increase in allowable cut for the next 50 years to a level of 30 MMfbm annually.

Much of the increased cut will come from thinnings because over one-half of the red pine type on the Forest in 1970 was under 40 years of age. Thinnings alone would produce an average of about 10 MMfbm a year in the 1990's, if thinnings are made every 10 years. Consequently, a significant opportunity exists in the next 50 years for expansion and development of timber industries in the market area of this Forest.

Table 4.--*Illustrative projections of future red pine sawtimber supplies for three alternative management levels*

Period (decades)	Thinning: Area	Thinning: Volume	Harvest cuts: Area	Harvest cuts: Volume	Total: Volume
	(Acres)	*MM fbm*[1]	(Acres)	*MM fbm*[1]	*MM fbm*[1]
ALTERNATIVE 1--LOW-INTENSITY MANAGEMENT					
1	[2]21,389	31.7	902	9.4	41.1
2	32,745	105.0	0	0	105.0
3	37,065	144.8	0	0	144.8
4	40,795	164.6	4,633	105.2	269.8
5	54,078	215.3	0	0	215.3
ALTERNATIVE 2--MEDIUM-INTENSITY MANAGEMENT					
1	[2]20,082	29.1	2,209	30.9	60.0
2	30,241	95.5	1,198	24.5	120.0
3	32,179	128.3	2,381	51.7	180.0
4	38,532	157.5	2,010	42.5	200.0
5	45,063	184.8	6,752	135.2	320.0
ALTERNATIVE 3--HIGH-INTENSITY MANAGEMENT					
1	[2]18,302	26.4	3,989	61.9	88.3
2	28,112	88.3	1,546	31.7	120.0
3	28,139	113.1	4,771	86.9	200.0
4	30,006	125.4	6,177	114.6	240.0
5	35,296	136.9	9,334	183.1	320.0

[1]International ¼-inch rule.

[2]Actual prescribed thinnings were 10,880 acres in decade 1. For simplicity in the RAM program, it was assumed that all stands with good stocking would be thinned from an average of 100 ft^2 of basal area to 90 ft^2. In practice, one-half that number were probably thinned from 110 ft^2 of basal area to 90 ft^2.

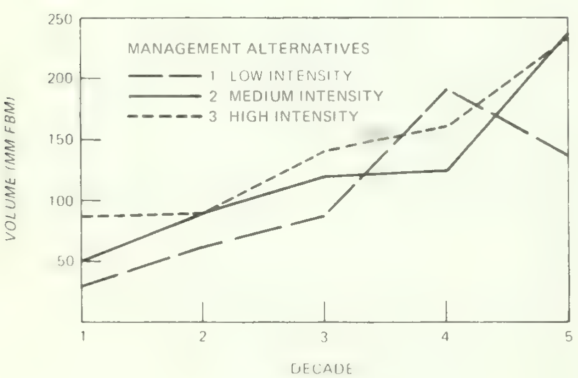


Figure 3.--*Projections of red pine sawtimber cut from the Chippewa National Forest per decade from stands 80 years and older for three management alternatives.*

Table 5.--*Average age of stands at harv[illegible]t for the three management alternative*

Decade	Management alternatives: Low-intensity	Medium-intensity	High-intensit
1	110	98	110
2	--	120	120
3	--	130	105
4	150	136	104
5	--	133	100

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OXFORD: 624:721.1:792(776)174.7. *Pinus resinosa.*
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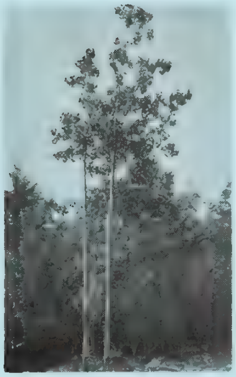

ESTIMATING ASPEN VOLUME AND WEIGHT FOR INDIVIDUAL TREES, DIAMETER CLASSES, OR ENTIRE STANDS

Bryce E. Schlaegel

NORTH CENTRAL FOREST EXPERIMENT STATION
FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

CONTENTS

Predicting Aspen Volume and Weight 1
Predicting Merchantable Stand Volume and Weight . . 11
Correcting for Form and Specific Gravity
Differences Between Stands 11
Literature Cited 12
Appendix I.--Procedures 13
Appendix II.--Example of Estimating Volume, Green
Weight, and Dry Weight 14
Appendix III.--Natural Logarithms 15

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1975

ESTIMATING ASPEN VOLUME AND WEIGHT FOR INDIVIDUAL TREES, DIAMETER CLASSES, OR ENTIRE STANDS

Bryce E. Schlaegel

Increased aspen (*Populus tremuloides* Michx.) utilization and weight scaling have created a demand for methods to estimate volumes and weights of whole trees and stands. So far there has been no satisfactory method for predicting volumes or weights for whole trees on a stand basis.

This paper presents equations and tables to estimate gross aspen volume, green weight, and dry weight for individual trees, diameter classes, or entire stands. Estimates can be made for bole wood only, bole wood and bark, or for whole trees including limbs. Estimates for wood and bark to merchantable top diameters from 2 to 7 inches can also be made. The predicting equations are based on a sample of 491 trees from 47 stands in northern Minnesota.

PREDICTING ASPEN VOLUME AND WEIGHT

Volume, green weight, and dry weight for individual trees, diameter classes, or stands can be easily estimated from measurements of basal area (B) and total height (H). Appropriate tree estimates (tables 1 to 3) or stand estimates (tables 4 to 6) are made by substituting measurements of the combined variable (BH) into the following allometric equations, which have been corrected for the bias that occurs when converting from logarithmic units to arithmetic units (Baskerville 1972) (this is an approximate correction):

		$S_{y.x}$	
Volume (ft^3)[1]			
Ln (bole wood)	=0.99554(Ln BH)-0.85373	0.055	(1)
Ln (bole wood + bark)	=0.99788(Ln BH)-0.73529	0.053	(2)
Ln (bole wood + bark + branches)	=0.98717(Ln BH)-0.47559	0.134	(3)
Green weight (lbs)			
Ln (bole wood)	=0.99719(Ln BH)+3.0070	0.052	(4)
Ln (bole wood + bark)	=0.99718(Ln BH)+3.1879	0.045	(5)
Ln (bole wood + bark + branches)	=0.98800(Ln BH)+3.4329	0.096	(6)
Dry weight (lbs)			
Ln (bole wood)	=0.99461(Ln BH)+2.3465	0.054	(7)
Ln (bole wood + bark)	=0.99889(Ln BH)+2.5006	0.055	(8)
Ln (bole wood + bark + branches)	=0.98996(Ln BH)+2.7422	0.094	(9)

These equations can be used to estimate volume and weight for individual trees, individual diameter classes, or entire stands.

[1] *All volumes and weights are from a 6-inch stump to the tree tip. Ln is a natural logarithm.* $R^2 = 0.99$.

Table 1.--*Gross cubic-foot volume per tree for bole wood, bole wood + bark, and for complete trees (the table can be used for either individual trees, for individual diameter classes, or for the complete stand using the quadratic mean diameter)*

Tree diameter, diameter class, or quadratic mean stand diameter (inches)	Tree height, average height of diameter class, or average stand height (ft)								
	20	30	40	50	60	70	80	90	100
1	0.047[1]	0.070	--	--	--	--	--	--	--
	.053[2]	.079	--	--	--	--	--	--	--
	.070[3]	.104	--	--	--	--	--	--	--
2	.186	.279	.372	--	--	--	--	--	--
	.210	.314	.418	--	--	--	--	--	--
	.274	.409	.543	--	--	--	--	--	--
3	.418	.626	.834	1.04	--	--	--	--	--
	.471	.705	.940	1.17	--	--	--	--	--
	.610	.911	1.21	1.51	--	--	--	--	--
4	.741	1.11	1.48	1.85	2.21	--	--	--	--
	.836	1.25	1.67	2.09	2.50	--	--	--	--
	1.08	1.61	2.13	2.66	3.19	--	--	--	--
5	--	1.73	2.30	2.88	3.45	4.02	--	--	--
	--	1.96	2.61	3.25	3.90	4.55	--	--	--
	--	2.50	3.32	4.13	4.95	5.76	--	--	--
6	--	--	3.31	4.14	4.96	5.78	--	--	--
	--	--	3.75	4.68	5.62	6.55	--	--	--
	--	--	4.75	5.93	7.09	8.26	--	--	--
7	--	--	--	5.62	6.74	7.86	8.98	--	--
	--	--	--	6.37	7.64	8.91	10.2	--	--
	--	--	--	8.03	9.62	11.2	12.8	--	--
8	--	--	--	7.34	8.80	10.3	11.7	13.2	14.6
	--	--	--	8.32	9.98	11.6	13.3	14.9	16.6
	--	--	--	10.5	12.5	14.6	16.6	18.7	20.7
9	--	--	--	9.28	11.1	13.0	14.8	16.7	18.5
	--	--	--	10.5	12.6	14.7	16.8	18.9	21.0
	--	--	--	13.2	15.8	18.4	21.0	23.6	26.2
10	--	--	--	11.4	13.7	16.0	18.3	20.5	22.8
	--	--	--	13.0	15.6	18.2	20.7	23.3	25.9
	--	--	--	16.2	19.4	22.6	25.8	29.0	32.2
11	--	--	--	13.8	16.6	19.3	22.1	24.8	27.6
	--	--	--	15.7	18.8	22.0	25.1	28.2	31.4
	--	--	--	19.6	23.5	27.3	31.2	35.0	38.9
12	--	--	--	16.5	19.7	23.0	26.3	29.5	32.8
	--	--	--	18.7	22.4	26.1	29.9	33.6	37.3
	--	--	--	23.3	27.9	32.5	37.0	41.6	46.2
13	--	--	--	19.3	23.1	27.0	30.8	34.6	38.5
	--	--	--	21.9	26.3	30.7	35.0	39.4	43.8
	--	--	--	27.3	32.6	38.0	43.4	48.7	54.1
14	--	--	--	22.4	26.8	31.3	35.7	40.1	44.6
	--	--	--	25.4	30.5	35.5	40.6	45.7	50.7
	--	--	--	31.6	37.8	44.0	50.2	56.4	62.6
15	--	--	--	--	30.8	35.9	41.0	46.1	51.1
	--	--	--	--	35.0	40.8	46.6	52.4	58.2
	--	--	--	--	43.3	50.4	57.5	64.6	71.7
16	--	--	--	--	--	40.8	46.6	52.4	58.2
	--	--	--	--	--	46.4	53.0	59.6	66.2
	--	--	--	--	--	57.3	65.3	73.4	81.4
17	--	--	--	--	--	46.0	52.5	59.1	65.6
	--	--	--	--	--	52.4	59.8	67.3	74.8
	--	--	--	--	--	64.6	73.7	82.7	91.8

(Table 1 cont. on next page)

(Table 1 cont.)

Tree diameter, diameter class, or quadratic mean stand diameter (inches)	Tree height, average height of diameter class, or average stand height (ft)								
	20	30	40	50	60	70	80	90	100
18	--	--	--	--	--	51.6	58.9	66.2	73.5
	--	--	--	--	--	58.7	67.1	75.4	83.8
	--	--	--	--	--	72.3	82.5	92.6	103
19	--	--	--	--	--	57.4	65.6	73.7	81.9
	--	--	--	--	--	65.4	74.7	84.0	93.3
	--	--	--	--	--	80.4	91.7	103	114
20	--	--	--	--	--	63.6	72.6	81.7	90.7
	--	--	--	--	--	72.4	82.8	93.1	103
	--	--	--	--	--	89.0	102	114	127

[1] Bole wood volume only, from 6-inch stump to tip of tree.
[2] Bole volume of wood + bark from 6-inch stump to tip of tree.
[3] Complete tree volume, including branches, from 6-inch stump to tip of tree.

Table 2.--*Gross green weight for bole wood, bole wood + bark, and for complete trees (the table can be used for either individual trees, for individual diameter classes, or for the complete stand using the quadratic mean diameter)*

(In lb/tree)

Tree diameter, diameter class, or quadratic mean stand diameter (inches)	Tree height, average height of diameter class, or average stand height (ft)								
	20	30	40	50	60	70	80	90	100
1	2[1]	3	--	--	--	--	--	--	--
	3[2]	4	--	--	--	--	--	--	--
	3[3]	5	--	--	--	--	--	--	--
2	9	13	18	--	--	--	--	--	--
	11	16	21	--	--	--	--	--	--
	14	20	27	--	--	--	--	--	--
3	20	30	40	50	--	--	--	--	--
	24	36	47	59	--	--	--	--	--
	30	45	60	75	--	--	--	--	--
4	35	53	70	88	105	--	--	--	--
	42	63	84	105	126	--	--	--	--
	54	80	106	133	159	--	--	--	--
5	--	82	110	137	164	192	--	--	--
	--	99	132	164	197	230	--	--	--
	--	125	165	206	247	288	--	--	--
6	--	--	158	197	237	276	--	--	--
	--	--	189	236	284	331	--	--	--
	--	--	237	296	354	412	--	--	--
7	--	--	--	268	322	375	429	--	--
	--	--	--	322	386	450	514	--	--
	--	--	--	401	480	559	638	--	--
8	--	--	--	350	420	490	560	629	699
	--	--	--	420	503	587	670	754	838
	--	--	--	522	625	728	831	933	1,040
9	--	--	--	443	531	619	708	796	884
	--	--	--	531	637	742	848	954	1,060
	--	--	--	659	789	919	1,050	1,180	1,310

(Table 2 cont. on next page)

(Table 2 cont.)

Tree diameter, diameter class, or quadratic mean stand diameter (inches)	Tree height, average height of diameter class, or average stand height (ft)								
	20	30	40	50	60	70	80	90	100
10	--	--	--	546	655	764	873	982	1,090
	--	--	--	655	785	916	1,050	1,180	1,310
	--	--	--	812	972	1,130	1,290	1,450	1,610
11	--	--	--	661	793	924	1,060	1,190	1,320
	--	--	--	792	950	1,110	1,270	1,420	1,580
	--	--	--	980	1,170	1,370	1,560	1,750	1,940
12	--	--	--	786	943	1,100	1,260	1,410	1,570
	--	--	--	942	1,130	1,320	1,510	1,690	1,880
	--	--	--	1,160	1,390	1,620	1,850	2,080	2,310
13	--	--	--	922	1,110	1,290	1,470	1,660	1,840
	--	--	--	1,110	1,330	1,550	1,770	1,990	2,210
	--	--	--	1,360	1,630	1,900	2,170	2,440	2,700
14	--	--	--	1,070	1,280	1,500	1,710	1,920	2,130
	--	--	--	1,280	1,540	1,790	2,050	2,300	2,560
	--	--	--	1,580	1,890	2,200	2,510	2,820	3,130
15	--	--	--	--	1,470	1,720	1,960	2,200	2,450
	--	--	--	--	1,760	2,060	2,350	2,640	2,930
	--	--	--	--	2,170	2,520	2,880	3,230	3,590
16	--	--	--	--	--	1,950	2,230	2,510	2,790
	--	--	--	--	--	2,340	2,670	3,000	3,340
	--	--	--	--	--	2,860	3,270	3,670	4,070
17	--	--	--	--	--	2,200	2,520	2,830	3,140
	--	--	--	--	--	2,640	3,010	3,390	3,770
	--	--	--	--	--	3,230	3,680	4,140	4,590
18	--	--	--	--	--	2,470	2,820	3,170	3,520
	--	--	--	--	--	2,960	3,380	3,800	4,220
	--	--	--	--	--	3,620	4,130	4,630	5,140
19	--	--	--	--	--	2,750	3,140	3,530	3,920
	--	--	--	--	--	3,290	3,760	4,230	4,700
	--	--	--	--	--	4,020	4,590	5,160	5,720
20	--	--	--	--	--	3,050	3,480	3,910	4,350
	--	--	--	--	--	3,650	4,170	4,690	5,210
	--	--	--	--	--	4,450	5,080	5,710	6,330

[1] Bole wood weight only, from 6-inch stump to tip of tree.
[2] Bole weight of wood + bark from 6-inch stump to tip of tree.
[3] Complete tree weight, including branches, from 6-inch stump to tip of tree.

Table 3.--*Gross oven-dry weight for bole wood, bole wood + bark, and for complete trees (the table can be used for either individual trees, for individual diameter classes, or for the complete stand using the quadratic mean diameter)*

(In lb/tree)

Tree diameter, diameter class, or quadratic mean stand diameter (inches)	Tree height, average height of diameter class, or average stand height (ft)								
	20	30	40	50	60	70	80	90	100
1	1[1]	2	--	--	--	--	--	--	--
	1[2]	2	--	--	--	--	--	--	--
	2[3]	3	--	--	--	--	--	--	--

(table 3 cont. on next page)

(Table 3 cont.)

Tree diameter, diameter class, or quadratic mean stand diameter (inches)	Tree height, average height of diameter class, or average stand height (ft)								
	20	30	40	50	60	70	80	90	100
2	5	7	9	--	--	--	--	--	--
	5	8	11	--	--	--	--	--	--
	7	10	14	--	--	--	--	--	--
3	10	15	20	26	--	--	--	--	--
	12	18	24	30	--	--	--	--	--
	15	23	30	38	--	--	--	--	--
4	18	27	36	45	54	--	--	--	--
	21	32	42	53	64	--	--	--	--
	27	40	54	67	80	--	--	--	--
5	--	42	56	71	85	99	--	--	--
	--	50	66	83	99	116	--	--	--
	--	63	83	104	124	145	--	--	--
6	--	--	81	101	121	142	--	--	--
	--	--	96	119	143	167	--	--	--
	--	--	119	149	178	208	--	--	--
7	--	--	--	138	165	192	220	--	--
	--	--	--	162	195	227	260	--	--
	--	--	--	202	242	282	322	--	--
8	--	--	--	180	215	251	287	322	358
	--	--	--	212	254	297	339	381	424
	--	--	--	263	315	367	419	471	523
9	--	--	--	227	272	317	362	407	452
	--	--	--	268	322	376	429	483	536
	--	--	--	332	398	464	529	595	660
10	--	--	--	280	336	391	447	502	558
	--	--	--	331	397	464	530	596	662
	--	--	--	409	490	571	652	733	813
11	--	--	--	338	406	473	540	607	674
	--	--	--	401	481	561	641	721	801
	--	--	--	494	592	690	787	885	982
12	--	--	--	402	482	562	642	722	802
	--	--	--	477	572	667	762	858	953
	--	--	--	587	704	820	935	1,050	1,170
13	--	--	--	472	565	659	753	846	940
	--	--	--	559	671	783	895	1,010	1,120
	--	--	--	688	824	960	1,100	1,230	1,370
14	--	--	--	547	655	764	872	981	1,090
	--	--	--	649	778	908	1,040	1,170	1,300
	--	--	--	797	955	1,110	1,270	1,430	1,580
15	--	--	--	--	752	876	1,000	1,130	1,250
	--	--	--	--	893	1,040	1,190	1,340	1,490
	--	--	--	--	1,090	1,270	1,460	1,640	1,810
16	--	--	--	--	--	996	1,140	1,280	1,420
	--	--	--	--	--	1,190	1,350	1,520	1,690
	--	--	--	--	--	1,450	1,650	1,860	2,060
17	--	--	--	--	--	1,120	1,280	1,440	1,600
	--	--	--	--	--	1,340	1,530	1,720	1,910
	--	--	--	--	--	1,630	1,860	2,090	2,330
18	--	--	--	--	--	1,260	1,440	1,620	1,800
	--	--	--	--	--	1,500	1,710	1,930	2,140
	--	--	--	--	--	1,830	2,090	2,350	2,600
19	--	--	--	--	--	1,400	1,600	1,800	2,000
	--	--	--	--	--	1,670	1,910	2,150	2,390
	--	--	--	--	--	2,040	2,320	2,610	2,900
20	--	--	--	--	--	1,550	1,770	1,990	2,210
	--	--	--	--	--	1,850	2,120	2,380	2,640
	--	--	--	--	--	2,250	2,570	2,890	3,210

[1] Bole wood weight only, from 6-inch stump to tip of tree.
[2] Bole weight of wood + bark from 6-inch stump to tip of tree.
[3] Complete tree weight, including branches, from 6-inch stump to tip of tree.

Table 4.--*Gross volume for bole wood, bole wood + bark, and for complete trees (the table can be used to estimate volumes of either individual diameter classes or the total stand)*
(In ft^3/acre)

Diameter class or stand basal area per acre (ft^2)	Average height of diameter class, or average stand height (ft)								
	20	30	40	50	60	70	80	90	100
10	83[1]	125	166	207	248	289	331	372	413
	95[2]	142	189	237	284	331	378	425	472
	116[3]	173	230	287	344	400	456	513	569
20	166	248	331	413	495	577	659	741	823
	189	284	378	472	567	661	755	849	943
	230	344	456	569	681	793	905	1,020	1,130
30	248	372	495	618	741	864	987	1,110	1,230
	284	425	567	708	849	990	1,130	1,270	1,410
	344	513	681	849	1,020	1,180	1,350	1,520	1,680
40	331	495	659	823	987	1,150	1,310	1,480	1,640
	378	567	755	943	1,130	1,320	1,510	1,700	1,880
	456	681	905	1,130	1,350	1,570	1,790	2,010	2,240
50	413	618	823	1,030	1,230	1,440	1,640	1,850	2,050
	472	708	943	1,180	1,410	1,650	1,880	2,120	2,350
	569	849	1,130	1,410	1,680	1,960	2,240	2,510	2,790
60	495	741	987	1,230	1,480	1,720	1,970	2,210	2,460
	567	849	1,130	1,410	1,700	1,980	2,260	2,540	2,820
	681	1,020	1,350	1,680	2,010	2,350	2,680	3,010	3,340
70	577	864	1,150	1,440	1,720	2,010	2,290	2,580	2,870
	661	990	1,320	1,650	1,980	2,310	2,640	2,960	3,290
	793	1,180	1,570	1,960	2,350	2,730	3,120	3,500	3,880
80	659	987	1,310	1,640	1,970	2,290	2,620	2,950	3,270
	755	1,130	1,510	1,880	2,260	2,640	3,010	3,390	3,760
	905	1,350	1,790	2,240	2,680	3,120	3,550	3,990	4,430
90	741	1,110	1,480	1,850	2,210	2,580	2,950	3,310	3,680
	849	1,270	1,700	2,120	2,540	2,960	3,390	3,810	4,230
	1,020	1,520	2,010	2,510	3,010	3,500	3,990	4,490	4,980
100	--	1,230	1,640	2,050	2,460	2,870	3,270	3,680	4,090
	--	1,410	1,880	2,350	2,820	3,290	3,760	4,230	4,700
	--	1,680	2,240	2,790	3,340	3,880	4,430	4,980	5,520
110	--	1,360	1,800	2,250	2,700	3,150	3,600	4,050	4,490
	--	1,550	2,070	2,590	3,110	3,620	4,140	4,650	5,170
	--	1,850	2,460	3,060	3,660	4,270	4,870	5,470	6,070
120	--	--	1,970	2,460	2,950	3,440	3,920	4,410	4,900
	--	--	2,260	2,820	3,390	3,950	4,510	5,080	5,640
	--	--	2,680	3,340	3,990	4,650	5,300	5,960	6,610
130	--	--	2,130	2,660	3,190	3,720	4,250	4,780	5,310
	--	--	2,450	3,060	3,670	4,280	4,890	5,500	6,110
	--	--	2,900	3,610	4,320	5,030	5,740	6,450	7,180
140	--	--	2,290	2,870	3,440	4,010	4,570	5,140	5,710
	--	--	2,640	3,290	3,950	4,610	5,260	5,920	6,580
	--	--	3,120	3,880	4,650	5,410	6,180	6,940	7,700
150	--	--	--	3,070	3,680	4,290	4,900	5,510	6,120
	--	--	--	3,530	4,230	4,940	5,640	6,340	7,050
	--	--	--	4,160	4,980	5,790	6,610	7,430	8,240
160	--	--	--	3,270	3,920	4,570	5,230	5,880	6,530
	--	--	--	3,760	4,510	5,260	6,010	6,760	7,510
	--	--	--	4,430	5,300	6,180	7,050	7,920	8,780
170	--	--	--	3,480	4,170	4,860	5,550	6,240	6,930
	--	--	--	4,000	4,790	5,590	6,390	7,190	7,980
	--	--	--	4,700	5,630	6,560	7,480	8,400	9,320
180	--	--	--	3,680	4,410	5,140	5,880	6,610	7,340
	--	--	--	4,230	5,080	5,920	6,760	7,610	8,450
	--	--	--	4,980	5,960	6,940	7,920	8,890	9,870

(Table 4 cont. on next page)

(Table 4 cont.)

Diameter class or stand basal area per acre (ft^2)	Average height of diameter class, or average stand height (ft)								
	20	30	40	50	60	70	80	90	100
190	--	--	--	3,880	4,660	5,430	6,200	6,970	7,740
	--	--	--	4,470	5,360	6,250	7,140	8,030	8,920
	--	--	--	5,250	6,290	7,320	8,350	9,380	10,410
200	--	--	--	4,090	4,900	5,710	6,530	7,340	8,150
	--	--	--	4,700	5,640	6,580	7,510	8,450	9,390
	--	--	--	5,520	6,610	7,700	8,780	9,870	10,950
210	--	--	--	4,290	5,140	6,000	6,850	7,700	8,550
	--	--	--	4,940	5,920	6,900	7,890	8,870	9,860
	--	--	--	5,790	6,940	8,080	9,220	10,350	11,490
220	--	--	--	4,490	5,390	6,280	7,170	8,070	8,960
	--	--	--	5,170	6,200	7,230	8,260	9,290	10,320
	--	--	--	6,070	7,260	8,460	9,650	10,840	12,030
230	--	--	--	4,700	5,630	6,570	7,500	8,430	9,360
	--	--	--	5,400	6,480	7,560	8,640	9,720	10,790
	--	--	--	6,340	7,590	8,840	10,080	11,330	12,570
240	--	--	--	4,900	5,880	6,850	7,820	8,800	9,770
	--	--	--	5,640	6,760	7,890	9,010	10,140	11,260
	--	--	--	6,610	7,920	9,220	10,510	11,810	13,110
250	--	--	--	5,100	6,120	7,130	8,150	9,160	10,180
	--	--	--	5,870	7,050	8,220	9,390	10,560	11,730
	--	--	--	6,880	8,240	9,600	10,950	12,300	13,640

[1] Bole wood volume only, from 6-inch stump to tip of tree.
[2] Bole volume of wood + bark from 6-inch stump to tip of tree.
[3] Complete tree volume, including branches, from 6-inch stump to tip of tree.

Table 5.--*Gross green weight for bole wood, bole wood + bark, and for complete trees (the table can be used to estimate weights of either individual diameter classes or the total stand)*
(In thousand lb/acre)

Diameter class or stand basal area per acre (ft^2)	Average height of diameter class, or average stand height (ft)								
	20	30	40	50	60	70	80	90	100
10	3.99[1]	5.97	7.96	9.94	11.9	13.9	15.9	17.9	19.8
	4.78[2]	7.16	9.53	11.9	14.3	16.7	19.0	21.4	23.8
	5.81[3]	8.68	11.5	14.4	17.2	20.0	22.9	25.7	28.5
20	7.96	11.9	15.9	19.8	23.8	27.7	31.7	35.6	39.6
	9.53	14.3	19.0	23.8	28.5	33.2	38.0	42.7	47.4
	11.5	17.2	22.9	28.5	34.1	39.7	45.3	50.9	56.5
30	11.9	17.9	23.8	29.7	35.6	41.6	47.5	53.4	59.3
	14.3	21.4	28.5	35.6	42.7	49.8	56.9	64.0	71.1
	17.2	25.7	34.1	42.5	50.9	59.3	67.7	76.0	84.4
40	15.9	23.8	31.7	39.6	47.5	55.4	63.3	71.2	79.0
	19.0	28.5	38.0	47.4	56.9	66.4	75.8	85.3	94.7
	22.9	34.1	45.3	56.5	67.7	78.8	89.9	101	112
50	19.8	29.7	39.6	49.5	59.3	69.2	79.0	88.9	98.7
	23.8	35.6	47.4	59.3	71.1	82.9	94.7	107	118
	28.5	42.5	56.5	70.5	84.4	98.3	112	126	140
60	23.8	35.6	47.5	59.3	71.2	83.0	94.8	107	118
	28.5	42.7	56.9	71.1	85.3	99.4	114	128	142
	34.1	50.9	67.7	84.4	101	118	134	151	167
70	27.7	41.6	55.4	69.2	83.0	96.8	111	124	138
	33.2	49.8	66.4	82.9	99.4	116	132	149	165
	39.7	59.3	78.8	98.3	118	137	156	176	195

(Table 5 cont. on next page)

(Table 5 cont.)

Diameter class: or stand basal: area per acre (ft^2)	Average height of diameter class, or average stand height (ft)								
	20	30	40	50	60	70	80	90	100
80	31.7	47.5	63.3	79.0	94.8	111	126	142	158
	38.0	56.9	75.8	94.7	114	132	151	170	189
	45.3	67.7	89.9	112	134	156	178	200	222
90	35.6	53.4	71.2	88.9	107	124	142	160	177
	42.7	64.0	85.3	107	128	149	170	191	213
	50.9	76.0	101	126	151	176	200	225	250
100	--	59.3	79.0	98.7	118	138	158	177	197
	--	71.1	94.7	118	142	165	189	213	236
	--	84.4	112	140	167	195	222	250	277
110	--	65.2	86.9	109	130	152	174	195	217
	--	78.2	104	130	156	182	208	234	260
	--	92.7	123	154	184	214	244	275	305
120	--	--	94.8	118	142	166	189	213	236
	--	--	114	142	170	198	227	255	283
	--	--	134	167	200	233	266	299	332
130	--	--	103	128	154	179	205	231	256
	--	--	123	154	184	215	246	276	307
	--	--	145	181	217	253	288	324	359
140	--	--	111	138	166	193	221	248	276
	--	--	132	165	198	231	264	297	330
	--	--	156	195	233	272	310	348	387
150	--	--	--	148	177	207	236	266	295
	--	--	--	177	213	248	283	319	354
	--	--	--	209	250	291	332	373	414
160	--	--	--	158	189	221	252	284	315
	--	--	--	189	227	264	302	340	377
	--	--	--	222	266	310	354	398	441
170	--	--	--	168	201	234	268	301	335
	--	--	--	201	241	281	321	361	401
	--	--	--	236	283	329	376	422	468
180	--	--	--	177	213	248	284	319	354
	--	--	--	213	255	297	340	382	424
	--	--	--	250	299	348	398	447	496
190	--	--	--	187	225	262	299	337	374
	--	--	--	224	269	314	359	403	448
	--	--	--	264	316	367	419	471	523
200	--	--	--	197	236	276	315	354	393
	--	--	--	236	283	330	377	424	471
	--	--	--	277	332	387	441	496	550
210	--	--	--	207	248	289	331	372	413
	--	--	--	248	297	347	396	446	495
	--	--	--	291	348	406	463	520	577
220	--	--	--	217	260	303	346	390	433
	--	--	--	260	311	363	415	467	518
	--	--	--	305	365	425	485	544	604
230	--	--	--	227	272	317	362	407	452
	--	--	--	271	326	380	434	488	542
	--	--	--	318	381	444	506	569	631
240	--	--	--	236	284	331	378	425	472
	--	--	--	283	340	396	453	509	565
	--	--	--	332	398	463	528	593	658
250	--	--	--	246	295	344	393	442	491
	--	--	--	295	354	413	471	530	589
	--	--	--	346	414	482	550	618	686

[1] Bole wood weight only, from 6-inch stump to tip of tree.
[2] Bole weight of wood + bark from 6-inch stump to tip of tree.
[3] Complete tree weight, including branches, from 6-inch stump to tip of tree.

Table 6.--*Gross oven-dry weight for bole wood, bole wood + bark, and for complete trees (the table can be used to estimate weights of either individual diameter classes or the total stand)*
(In thousand lb/acre)

Diameter class: or stand basal: area per acre (ft²)	Average height of diameter class, or average stand height (ft) 20	30	40	50	60	70	80	90	100
10	2.03[1]	3.04	4.05	5.05	6.06	7.06	8.06	9.07	10.1
	2.42[2]	3.63	4.84	6.05	7.26	8.47	9.68	10.9	12.1
	2.94[3]	4.40	5.85	7.29	8.73	10.2	11.6	13.0	14.5
20	4.05	6.06	8.06	10.1	12.1	14.1	16.1	18.1	20.1
	4.84	7.26	9.68	12.1	14.5	16.9	19.3	21.8	24.2
	5.85	8.73	11.6	14.5	17.3	20.2	23.1	25.9	28.8
30	6.06	9.07	12.1	15.1	18.1	21.1	24.0	27.0	30.0
	7.26	10.9	14.5	18.1	21.8	25.4	29.0	32.6	36.2
	8.73	13.0	17.3	21.6	25.9	30.2	34.5	38.7	43.0
40	8.06	12.1	16.1	20.1	24.0	28.0	32.0	36.0	40.0
	9.68	14.5	19.3	24.2	29.0	33.8	38.7	43.5	48.3
	11.6	17.3	23.1	28.8	34.5	40.1	45.8	51.5	57.1
50	10.1	15.1	20.1	25.0	30.0	35.0	40.0	44.9	49.9
	12.1	18.1	24.2	30.2	36.2	42.3	48.3	54.3	60.4
	14.5	21.6	28.8	35.9	43.0	50.1	57.1	64.2	71.2
60	12.1	18.1	24.0	30.0	36.0	42.0	47.9	53.9	59.8
	14.5	21.8	29.0	36.2	43.5	50.7	58.0	65.2	72.4
	17.3	25.9	34.5	43.0	51.5	60.0	68.4	76.9	85.3
70	14.1	21.1	28.0	35.0	42.0	48.9	55.9	62.8	69.7
	16.9	25.4	33.8	42.3	50.7	59.2	67.6	76.1	84.5
	20.2	30.2	40.1	50.1	60.0	69.8	79.7	89.6	99.4
80	16.1	24.0	32.0	40.0	47.9	55.9	63.8	71.7	79.6
	19.3	29.0	38.7	48.3	58.0	67.6	77.3	86.9	96.6
	23.1	34.5	45.8	57.1	68.4	79.7	91.0	102	113
90	18.1	27.0	36.0	44.9	53.9	62.8	71.7	80.6	89.5
	21.8	32.6	43.5	54.3	65.2	76.1	86.9	97.8	109
	25.9	38.7	51.5	64.2	76.9	89.6	102	115	127
100	--	30.0	40.0	49.9	59.8	69.7	79.6	89.5	99.4
	--	36.2	48.3	60.4	72.4	84.5	96.6	109	121
	--	43.0	57.1	71.2	85.3	99.4	113	127	142
110	--	33.0	43.9	54.9	65.8	76.7	87.6	98.4	109
	--	39.9	53.1	66.4	79.7	92.9	106	119	133
	--	47.2	62.8	78.3	93.8	109	125	140	156
120	--	--	47.9	59.8	71.7	83.6	95.5	107	119
	--	--	58.0	72.4	86.9	101	116	130	145
	--	--	68.4	85.3	102	119	136	153	169
130	--	--	51.9	64.8	77.7	90.5	103	116	129
	--	--	62.8	78.5	94.1	110	125	141	157
	--	--	74.1	92.4	111	129	147	165	183
140	--	--	55.9	69.7	83.6	97.5	111	125	139
	--	--	67.6	84.5	101	118	135	152	169
	--	--	79.7	99.4	119	139	158	178	197
150	--	--	--	74.7	89.5	104	119	134	149
	--	--	--	90.5	109	127	145	163	181
	--	--	--	106	127	149	169	190	211
160	--	--	--	79.6	95.5	111	127	143	159
	--	--	--	96.6	116	135	154	174	193
	--	--	--	113	136	158	181	203	225
170	--	--	--	84.6	101	118	135	152	169
	--	--	--	103	123	144	164	185	205
	--	--	--	120	144	168	192	216	239
180	--	--	--	89.5	107	125	143	161	178
	--	--	--	109	130	152	174	195	217
	--	--	--	127	153	178	203	228	253

(Table 6 cont. on next page)

(Table 6 cont.)

Diameter class or stand basal area per acre (ft^2)	Average height of diameter class, or average stand height (ft)								
	20	30	40	50	60	70	80	90	100
190	--	--	--	94.5	113	132	151	170	188
	--	--	--	115	138	160	183	206	229
	--	--	--	134	161	188	214	241	267
200	--	--	--	99.4	119	139	159	178	198
	--	--	--	121	145	169	193	217	241
	--	--	--	142	169	197	225	253	281
210	--	--	--	104	125	146	167	187	208
	--	--	--	127	152	177	203	228	253
	--	--	--	149	178	207	236	266	295
220	--	--	--	109	131	153	174	196	218
	--	--	--	133	159	186	212	239	265
	--	--	--	156	186	217	248	278	309
230	--	--	--	114	137	160	182	205	228
	--	--	--	139	166	194	222	250	277
	--	--	--	162	195	227	259	291	323
240	--	--	--	119	143	167	190	214	238
	--	--	--	145	174	203	231	260	289
	--	--	--	169	203	236	270	303	337
250	--	--	--	124	149	173	198	223	247
	--	--	--	151	181	211	241	271	301
	--	--	--	176	211	246	281	316	351

[1] Bole wood weight only, from 6-inch stump to tip of tree.
[2] Bole weight of wood + bark from 6-inch stump to tip of tree.
[3] Complete tree weight, including branches, from 6-inch stump to tip of tree.

Individual tree volume or weight estimates are obtained from the equations when B is the individual tree basal area and H is the total tree height. Bole wood volume estimates agree closely with Table 3 of the composite volume tables (Gevorkiantz and Olsen 1955).

A further extension of the individual tree estimate is to estimate volume or weight by diameter classes to derive stocking tables. These estimates can be readily calculated from the equations by using diameter class basal area for B and the average total height of the trees in that diameter class for H.

Finally, volume or weight estimates can be made on a total stand basis. In this case B is the total stand basal area and H is the average weighted total height of all the trees in the stand (the weighting factor for each tree is its squared diameter). This average height estimate is the same as the height of the tree of mean basal area.

A simple way to find diameter class heights and average stand height is to measure total tree heights on a sample of trees while cruising the stands. Make sure that all diameter classes are represented, usually 15 to 25 trees. Fit a height/diameter curve to these data by regression. Any suitable model can be used, but one of the more convenient is the second degree polynomial of the form:

$$\text{total tree height}=b_0+b_1(\text{dbh})+b_2(\text{dbh})^2. \quad (10)$$

Diameter-class heights can now be found from the height/diameter equation using diameter class midpoint as the estimator. Average total stand height can be found using the quadratic mean stand diameter in the height/diameter equation. Or, it can be found from the sample tree height/diameter data:

$$\text{average stand height}=\text{sum}(D^2H)/\text{sum } D^2.$$

Because the volume estimates from eq. 1 agree so closely with the composite tables, which are applicable for a number of Lake States species, dry weight equations presented here for aspen bole wood could probably be extended to these other species, after correcting for specific gravity differences between species, as described in a later section. Bark volumes, green

weights, and total weights for other species could not be extended in this manner due to differences between species in wood/bark ratios, moisture content, and crowns.

PREDICTING MERCHANTABLE STAND VOLUME AND WEIGHT

Although whole-tree harvesting of aspen is becoming increasingly important, there is still a need to estimate volumes and weights to various top diameters. Tree and stand volumes and weights can be estimated to top diameters of 2 to 7 inches by using the ratio-estimation technique (Schlaegel 1971, 1974). The percent of weight and volume to various top diameters can be estimated from the following asymptotic equations:

Percent[2] *of bole to*

2-inch top[3]	$=0.994-(1.468)(0.383)^D$	(11)
3-inch top	$=0.984-(4.469)(0.389)^D$	(12)
4-inch top	$=0.981-(2.826)(0.556)^D$	(13)
5-inch top	$=0.967-(5.248)(0.597)^D$	(14)
6-inch top	$=0.947-(9.662)(0.598)^D$	(15)
7-inch top	$=0.971-(5.752)(0.697)^D$	(16)

where D = diameter of tree of mean basal area.

From these equations (or table 7) the merchantable bole as a percent of the total bole can be used with the estimate of total bole volume or weight (tables 1 to 6) to estimate volumes and weights to specified top diameters for individual trees, for all the trees in a diameter class, or for the total stand. NOTE: When using the ratio equations to estimate merchantable volume or weight, only the bole volumes and weights of trees with a d.b.h. larger than the indicated top diameter can be used.

CORRECTING FOR FORM AND SPECIFIC GRAVITY DIFFERENCES BETWEEN STANDS

Additional accuracy can be obtained by adjusting for form and specific gravity differences when estimating bole volume and weight. The average form factor for these Minnesota aspen estimates is 0.413 and the average wood specific gravity is 0.391.

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[2] *Expressed as a decimal*

[3] *Top diameters were measured outside bark.*

Table 7.--*Merchantable bole based on top diameter outside bark and quadratic mean stand diameter*[1]
(In decimal percent)

Quadratic mean stand diameter (inches)	Top diameter outside bark (inches)					
	2	3	4	5	6	7
2	0.78	0.31	--	--	--	--
3	.91	.72	0.50	--	--	--
4	.96	.88	.71	0.30	--	--
5	.98	.94	.83	.57	0.21	--
6	.99	.97	.90	.73	.51	0.31
7	.99	.98	.93	.83	.68	.51
8	.99	.98	.96	.88	.79	.65
9	.99	.98	.97	.92	.85	.75
10	.99	.98	.97	.94	.89	.82
11	.99	.98	.98	.95	.91	.86
12	.99	.98	.98	.96	.93	.90
13	.99	.98	.98	.96	.93	.92
14	.99	.98	.98	.96	.94	.93
15	.99	.98	.98	.96	.94	.95

[1] Model form: decimal percent = $a + b(r)^D$. Where a = the asymptote of percent, b = the change in percent as D goes from 0 to infinity, r = the factor by which the deviation of percent is reduced from its asymptotic value by each unit step of D, D = quadratic mean stand diameter (Stevens 1951).

Form factor can be estimated several ways. The best way is to cut a few sample trees in the stand, calculate tree volumes from stem measurements, and calculate form factors as the ratio of tree volume to the volume of a cylinder, with diameter equal to d.b.h. and a length equal to total height. Tree form factors differ little from tree to tree in the same stand except for intermediate and suppressed trees. These differences in small trees can be minimized when averaging the tree form factors if each tree is weighted by its diameter squared and a weighted average calculated.

If destructive sampling is not feasible, average stand form factor can be estimated from the stand age and average stand form quotient (FQ), i.e., diameter at ½-tree height over d.b.h.:

$$\text{average stand form factor} = -0.073 + 0.737\,(FQ) - 0.000545\,(\text{age}). \quad (17)$$

This equation accounts for 84 percent of regression variation and has a standard error of 0.009.

After average stand form factor has been estimated, adjust stand bole wood volume and weight estimates by the percent difference that exists between the actual stand form and the average stand form given above. For instance, if you know that the stand in question has an average form factor of 0.445 instead of 0.413, you would adjust the weight or volume estimate up 7.7 percent.

Adjust stand ovendry wood weight for differences in specific gravities between stands by relating average increment core specific gravity to average stand specific gravity.[4] Take enough large diameter (½-inch) increment cores to give a reliable and accurate estimate (Freese 1967), then compute an arithmetic average of the core specific gravities.

$$\text{Avg. stand wood specific gravity} = 0.031 + 0.963\ (\text{avg. core SG}). \qquad (18)$$

$$R^2 = 0.86 \qquad Sy{\cdot}x = 0.008$$

Ovendry wood weight estimates from equation 7 can then be adjusted by the percent difference between 0.391 and the stand specific gravity estimate.

[4] *Bryce E. Schlaegel. Estimating aspen specific gravity from increment cores. (In preparation.)*

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APPENDIX I.--PROCEDURES

In an aspen weight-yield study begun in 1970, a total of 491 trees in 47 stands were sampled. Stand characteristics measured were:

	Mean	*Range*
Age (yr)	42	11-99
Site index, height at age 50 years (ft)	70	47-85
Basal area (ft^2/acre)	126	59-215
Average stand diameter (in. at 4.5 ft)	6.4	2-13
Average total stand height (ft)	62	28-86
Average stand wood (sp. gr.)	0.39	0.34-0.45
Average stand bark (sp. gr.)	0.55	0.47-0.66
Average stand wood moisture content (percent)	82	60-105
Average stand bark moisture content (percent)	80	62-120

A wide range of growing conditions is represented. Soils ranged from very dry coarse sands to clay loams to peat. Climate in the study area is continental with mild summers and cold winters. Precipitation averages 25 inches per year, two-thirds falling from May through September. Average temperatures range from 6°F in January to 67°F in July. About 75 percent of the commercial aspen range in Minnesota is represented by the 47 sample stands.

Sample locations were chosen in stands where aspen composed at least 75 percent of the overstory. At each sample location a plot was measured for stand characteristics. Plot size ranged from 1/100 to 1/10 acre, depending on the number of trees in the stand; the higher the density, the smaller the plot. Sample trees were selected using a basal area factor (BAF) prism to allow cutting 9 to 13 trees. Height to crown and total height were measured on each felled sample tree; then the tree was cut into 4-foot bolts and weighed. A 1-inch-thick disc was removed from each 4-foot section and sealed in a polyethylene bag for laboratory determination of moisture content and specific gravity. All limbs were weighed from a subsample of four trees on each plot.

In the laboratory, both wood and bark moisture content and specific gravity were determined as follows:

1. Wood and bark were separated with a knife.
2. Each component was weighed green.
3. Both wood and bark were soaked in water for an hour to ensure complete swelling.
4. Volumes were obtained by immersion (Heinrichs and Lassen 1970).
5. Wood and bark were ovendried at 103°C for at least 24 hours or until weight loss was completed.

$$\text{Wood or bark moisture content} = \frac{\text{green weight} - \text{ovendry weight}}{\text{ovendry weight}} .$$

$$\text{Specific gravity} = \frac{\text{ovendry wood (bark) weight (gm)}}{\text{green wood (bark) volume (cc)}} .$$

Because the amount of wood and bark decreases up the tree and the ratio of wood to bark also decreases up the tree, a simple arithmetic mean for tree moisture content and specific gravity cannot be used. Each disc wood and bark moisture content and specific gravity is weighted by its respective diameter squared. Thus, average tree moisture content = sum (disc diameter squared x disc moisture content)/sum disc diameters squared.

Bolt volumes were calculated from Smalian's formula. Total tree volumes and green weights were found by summing the values for each 4-foot bolt. Ovendry wood and bark weights were estimated for each bolt from average disc specific gravity and the appropriate bolt component volume.

Sample tree volumes and weights were related to BH by ratio regression estimates (Freese 1964). These ratios were used to calculate unit area component volumes and weights to various stem top diameters. Allometric regression equations were then used to estimate total stand volume and weight from various stand characteristics.

APPENDIX II.--EXAMPLE OF ESTIMATING VOLUME, GREEN WEIGHT, AND DRY WEIGHT

This example uses average stand table and height data from three 40-year-old stands, site index 75, used in this study. Table 8 gives the stand table and height data that were obtained from field measurements. It also gives results from intermediate steps in calculating some specific yield information.

Table 8.--*Example showing averages from three stands in this study, each 40 years old with a site index of 75*

Instruction step		2,3	4	7	8b	8b	8b	9	9
Equation used		10			1	5	9	1,14	5,12
D class	Trees	Height	Basal area	BxH	Bole wood volume	Green wt. wood + bark	Dry wood, bark, branches	Bole wood to 5 inch top	Green bole wood + bark to 3 inch top
	No.	*ft.*	*ft^2*		*ft^3*	*lbs*	*lbs*	*ft^3*	*lbs*
3	7	38	0.3	11	5	265	167	--	--
4	73	48	6.4	307	127	7,322	4,499	--	7,141
5	60	56	8.2	459	190	10,934	6,699	--	10,663
6	93	61	18.3	1,116	461	26,519	16,143	365	25,862
7	93	64	24.9	1,594	657	37,839	22,975	521	36,901
8	87	66	30.4	2,006	826	47,589	28,847	655	46,409
9	40	66	17.7	1,168	482	27,751	16,888	382	27,063
10	--	--	--	--	--	--	--	--	--
11	7	67	4.6	308	128	7,345	4,513	101	7,163
Total	460		110.8	6,969	2,876	165,564	100,731	2,024	161,202
		Sum of classes 6 inches +			2,554				
		Sum of classes 4 inches +				165,299			

Step

1. Establish a stand table for the area to be estimated.

2. Measure a representative sample of trees for diameter and height and fit a height/diameter curve by either freehand or by regression methods.

3. Find the average height for the midpoint of each diameter class from the curve or equation.

4. Compute the basal area of each diameter class.

5. Find the diameter of the tree of average basal area for use in equations 11 to 16 from:

$$\bar{D} = \sqrt{\frac{\frac{\text{Total basal area}}{\text{Total number of trees}}}{0.005454}} = \sqrt{\frac{\frac{110.8}{460}}{0.005454}} =$$

$$\sqrt{\frac{0.241}{0.005454}} = \sqrt{44.16} = 6.6 \text{ inches}$$

6a. Find the height of the tree of mean stand basal area from the ht./d.b.h. curve, in this case 63 feet, or

b. Calculate weighted average stand height from sample tree ht./d.b.h. data (weighted average height = sum ((d.b.h.)^2 x total height)/sum (d.b.h.)^2), as in the following:

D	H	D^2	D^2H
4	50	16	800
5	58	25	1,425
6	63	36	2,232
7	66	49	3,185
8	68	64	4,288
		190	11,930

$\bar{D}$ = 11,930/190 = 63 ft.

7. Multiply the basal area in each D class by the height of that class to obtain BH.

8. Find the estimated volumes or weights from equations 1 to 9 by any of the following:

a. Individual trees--using tree basal area x height

b. Diameter class--using D class basal area x D class height.
ex.: table 8--6-inch diameter class

Ln (bole wood volume)
=0.99554(Ln BH) - 0.85373 Equation 1
=0.99554(Ln 1116) - 0.85373
=0.99554(7.02) - 0.85373
=6.13
Bole wood volume
=antilog (6.13)
=461 ft^3

or

Ln (Green bole wood + bark)
=0.99718(Ln BH) + 3.1879 Equation 5
=0.99718(Ln 1116) + 3.1879
=0.99718(7.02) + 3.1879
=10.19
Green bole wood + bark
=antilog (10.19)
=26,519 lbs

c. Total stand--using stand basal area x height of mean tree:

Stand basal area (B)
=110.8 ft^2
Mean tree height (H)
=63 ft

BH
$=6,980.4$
Bole wood volume (total stand)
$=\text{antilog}\ (0.99554\ (\text{Ln}\ 6,980.4) - 0.85373)$
$=2,857\ ft^3$

d. Total stand--by finding volume of mean tree and multiplying by the number of trees in the stand.

Diameter of mean tree
$=6.6$ inches
Basal area of mean tree
$=0.005454\ (6.6)^2 = 0.24\ ft^2$
Height of mean tree
$=63$ ft
BH
$=14.97$
Volume of mean tree
$=6.3\ ft^3$ Equation 1
Numbers of trees in stand
$=460$
Stand volume
$=6.3 \times 460 = 2,897\ ft^3$

9. Find bole volume and weight information to the desired top diameter for:

a. Each diameter class:
By using mean basal area to find the appropriate ratio from equations 11 to 16 and multiplying that ratio times the total bole volume or weight of that D class.
In this example:
Find ratio of volume to 5-inch top using equation 14.

Percent of bole to 5-inch top
$=0.967 - (5.248)\ (0.597)^{\bar{D}}$ Equation 14

$\bar{D}$ =average stand diameter = 6.6 inches
Percent to 5-inch top
$=0.967 - (5.248)\ \text{antilog}\ ((6.6)\ (\text{Ln}\ 0.597))$
$=0.967 - (5.248)\ \text{antilog}\ ((6.6)\ (-0.52))$
$=0.967 - (5.248)\ \text{antilog}\ (-3.40)$
$=0.967 - (5.248)\ (0.033)$
$=0.967 - 0.174$
$=0.793$
Bole wood volume to 5-inch top in 6-inch class$=0.793 \times 461 = 365\ ft^3$
Bole wood volume to 5-inch top in 7-inch class$=0.793 \times 657 = 521\ ft^3$

b. For total stand:
By using the mean basal area to find the appropriate ratio from equations 11 to 16 and multiplying this ratio times the stand volume or weight of only those trees that are larger than the top diameter you are using--i.e., if you are finding stand volume to a 5-inch top, find the total stand volume for boles of all trees 6 inches and larger. For our example apply the percent found in (a) above to the total bole volume of all trees in 6-inch class and larger. Total stand bole wood volume to 5-inch top = $0.793 \times 2,554 = 2,024$.

10. Various stand estimates can be found by using equations 1 to 9 and 11 to 16 as in the examples presented.

APPENDIX III.--NATURAL LOGARITHMS

Finding Natural Logarithms

Large logarithms and antilogs can be easily handled by hand if you have a natural logarithm table available for numbers from 0.1 to 10. First, divide the number by 10, 100, etc., to reduce it to a number we can find in the table. Then, find the natural log of the reduced number. Finally, add to that logarithm the natural logarithm of 10, 100, etc. The following tabulation will help the user:

$\ln 10 = \ln 10^1 = 1 \ln 10 = 2.303$
$\ln 100 = \ln 10^2 = 2 \ln 10 = 4.605$
$\ln 1000 = \ln 10^3 = 3 \ln 10 = 6.908$
$\ln 10,000 = \ln 10^4 = 4 \ln 10 = 9.210$
$\ln 100,000 = \ln 10^5 = 5 \ln 10 = 11.513.$

As an example, suppose we wish to find the natural logarithm of 6,980.4--as in 8c, Appendix II. Because the largest number for which we can find the logarithm in our table is 10, we have to reduce the 6,980.4 by some factor, 10, 100, etc., to a number that we can handle. Logically, we divide by 1,000 obtaining 6.9804 that has a natural log from the table of 1.943. Now, to obtain the natural logarithm of 6,980.4 we must add to 1.943 the logarithm of 1,000. Because $1,000 = 10^3$, the natural log of $1,000 = 3 \ln 10 = 6.908$. So the natural log of $6,980.4 = \ln 6.9804 + 3 \ln 10 = 1.943 + 6.908 = 8.851$.

Finding Natural Antilogarithms

Finding the antilogarithm of a number that is larger than those in our table is somewhat more complicated. With our natural log table for numbers to 10, the largest number we can find the antilog of is 2.303

(which is ln 10). Again, we must reduce the large number, in this case now a logarithm, to a number less than 2.303, that is available in the table.

As an example, find the natural antilogarithm of 10.19 (from 8b, Appendix II). We have to divide 10.19 by some number (X) so that $10.19 \div X \leq 2.303$. If we divide 10.19 by 5, we get 2.038, that has a natural antilog, from the table, of 7.675. If we now multiply 7.675 times itself X - 1 times we will obtain the natural antilogarithm of 10.19, which is 26,631. Or, 7.675 X 7.675 X 7.675 X 7.675 X 7.675 = 26,631.

We could also have divided by any other number larger than 5, say 6. Then we would have $10.19 \div 6 = 1.698$, the antilog of which is 5.463. Multiply 5.463 times itself 5 times (6-1) to obtain the antilog of 10.19 = 26,582. Notice this does not agree with the example above due to rounding errors. The smaller value of X will mean less paperwork and more accurate estimates.

U.S. GOVERNMENT PRINTING OFFICE: 1975-668-748

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1975. Estimating aspen volume and weight for individual trees, diameter classes, or entire stands. USDA For. Serv. Gen. Tech. Rep. NC-20, 16 p. North Cent. For. Exp. Stn., St. Paul, Minn.

Presents allometric volume and weight equations for Minnesota quaking aspen. Volume, green weight, and dry weight estimates can be made for wood, bark, and limbs on the basis of individual trees, diameter classes, or entire stands.

OXFORD: 524.2:176.1(*Populus tremuloides*). KEY WORDS: specific gravity, weight-yield, merchantable ratio estimates, top diameter, form.

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USDA FOREST SERVICE
GENERAL TECHNICAL REPORT NC- 21

INTENSIVE PLANTATION CULTURE

FIVE
YEARS
RESEARCH

NORTH CENTRAL FOREST EXPERIMENT STATION
FOREST SERVICE • U.S. DEPARTMENT OF AGRICULTURE

North Central Forest Experiment Station
John H. Ohman, Director
Forest Service, U.S. Department of Agriculture
Folwell Avenue
St. Paul, Minnesota 55108

1976

INTENSIVE PLANTATION CULTURE

Five Years Research

CONTENTS PAGE

History and Organization of the Maximum Wood Yield Program
David H. Dawson 1

Yields of Intensively Grown *Populus*: Actual and Projected
Alan R. Ek and David H. Dawson 5

Some Physiological Applications for Intensive Culture
Philip R. Larson, Richard E. Dickson, and J. G. Isebrands 10

Controlled-Environment Selection of *Populus* Clones
Paul H. Wray and Lawrence C. Promnitz 19

Rapid Selection Techniques for Identifying Superior Clones
Lawrence C. Promnitz and Paul H. Wray 25

Biomass Studies in Intensively Managed Forest Stands
J. Zavitkovski 32

Cooperative and Related Forest Research at the Institute of Paper Chemistry
Dean W. Einspahr 39

Determining Moisture-Nutrient Requirements for Maximum Fiber Yield
Edward A. Hansen 43

Some Problems of Establishing and Managing Intensively Cultured Planted Stands
Howard M. Phipps and Nonan V. Noste 47

Increased Yields of Intensively Managed Plantations of Improved Jack Pine and White Spruce
Hans Nienstaedt and Richard M. Jeffers 51

Propagation Research in the Establishment of Maximum Yield Plantations
Howard M. Phipps 60

Epidemiology and Impact of *Melampsora medusae* Leaf Rust on Hybrid Poplars
Katharine D. Widin and Arthur L. Schipper, Jr. 63

Hybrid Poplar Diseases and Disease Resistance
Arthur L. Schipper, Jr. 75

Poplar Plantation Density Influences Foliage Disease
Arthur L. Schipper, Jr. 81

CONTENTS, cont.

PAGE

Detection and Elimination of Viruses in Poplars
J. G. Berbee, J. O. Omuemu, R. R. Martin, and J. D. Castello . . 85

Impact of Insects on Trees Planted for Maximum Fiber Production
Wayne Myers, Louis Wilson, and John Bassman. 92

Economic Feasibility of Intensive Culture
Dietmar W. Rose and Robert D. Kallstrom. 96

Utilization Advantages of Material Produced in Maximum Fiber Yield Plantations
John B. Crist. 109

Pulp and Paper Characteristics of Populus Hybrids
Ronald D. Neuman 112

"Agricultural" Poplars as a Raw Material for Structural Particleboard
Robert L. Geimer 115

HISTORY AND ORGANIZATION OF THE MAXIMUM WOOD YIELD PROGRAM

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"Intensive culture" can be defined for this conference as the application of several cultural practices to the establishment and management of plantations with the objective of increasing the quantity and quality of wood produced. The Multiproject Program for maximum yield and intensive culture of planted stands includes research studies in genetics, silviculture, soils, plant nutrient and water needs, utilization, and economics, all directed toward the common goal.

Before the detailed reports of 5 years' progress in specific research areas are presented, it would appear worthwhile to present an overview of the structure, history, and rationale of the organization that provides the framework for the specific studies.

Moreover, we need to discuss terms. The terms "intensive culture" and "maximum yield" have been interpreted in many ways. For purposes of this conference and series of papers, "intensive culture" means the application of several--as opposed to one or two--cultural practices to the establishment and management of plantations with the objective of increasing the quantity and quality of wood produced. "Maximum yield" means the amount of fiber produced when *all* environmental and genetic factors affecting tree growth are optimized.

The program under review is officially termed: "Multiproject Program II: Maximum Yield and Intensive Culture of Planted Stands"--including species selection, cultural methods technology, harvesting techniques, utilization, and economics.

The research mission of the program is "to develop the most biologically efficient and economically feasible method of producing maximum commercial wood per acre by means of a systems approach involving the unified effort of several disciplines."

Obviously, the program is somewhat dissimilar from most other Forest Service research operations in that it encompasses several "specialties"--not just one. That is, it is not a research effort in, for example, silviculture, *or* pathology, *or* economics, *or* genetics, but a team of research people trained in different elements of the broad field of forestry cooperating to accomplish a specific research objective.

The justification for a research program to explore the possibility of maximizing wood yields is emphasized in Forest Resource Report 29, *The Outlook for Timber in the United States* (USDA Forest Service 1973): "...with rising relative prices of 1.5 percent per year above the 1970 trend level of lumber and somewhat smaller price increases for plywood, woodpulp, and other items, projected total timber demands by the year 2000 approximate 19 billion cubic feet. This latter projection includes increases in demand of 5 percent for saw logs between 1970 and 2000, 58 percent for veneer logs, and 130 percent for roundwood pulpwood."

or lumber. Hence, a Station wood technologist is cooperating with the Forest Products Department of the School of Forestry, University of Minnesota, on pulping studies of the "new" intensively grown trees. The Forest Products Laboratory at Madison is cooperating in research involving the use of the plant material in particleboard.

Intensively managed plantations will certainly require special mechanized planting and harvesting techniques. The Engineering Systems Work Unit at Houghton, Michigan, is researching in this area.

Growing dense stands of trees of the same species under near optimized conditions, in some cases irrigated, requires attention to possible disease and insect problems if yields are to be maximized. The Diseases of Forests and Christmas Tree Plantations project at St. Paul and the Plant Pathology Department of the University of Wisconsin have set up several studies to consider disease problems. The Work Unit "Insects Affecting Forest Ecosystems" is cooperating with Michigan State University in studying the impact of insect damage on growth and yield of intensively cultured plantations.

Perhaps the most frequent question regarding maximum yield or intensive culture research is, "Is it economical?" The University of Minnesota, Department of Forest Resources, cooperating with the North Central Station's "Economics of Forest Land Management" Work Unit, has explored and is continuing to study economic feasibility of intensive culture systems in relation to other alternatives.

Close liaison has been maintained with forest managers since the inception of the program. The problem analyses and study plans have been reviewed by managers and cooperating researchers as the program has progressed. Also, an attempt has been made to keep abreast of basic research results constantly being generated worldwide.

The following reports present in detail the research in progress and provide a base for joint planning by managers and researchers for the period ahead.

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YIELDS OF INTENSIVELY GROWN POPULUS: ACTUAL AND PROJECTED

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Yields of Populus 'Tristis #1' *based on 4 years of growth under intensive culture at square spacings of 0.75, 1, and 2 feet are reported. Stem and branch wood yields of up to 45,132 pounds per acre were recorded. Tree growth and competition data from these plots were then used to calibrate a stand growth simulation model to enable projections of these and three wider spacings to 10 to 25 years. Over the range of spacings examined (0.75 to 12.7 feet), the mean annual growth of projections peaked at 8 to 15 years with stem and branch wood dry weights in the range of 13,881 to 16,584 pounds per acre per year, five to six times that possible from reported natural aspen stands. Projected tree sizes and growth patterns are discussed in relation to rotation age and related management alternatives. Continuing growth and yield studies are also outlined.*

Intensive cultural practices are receiving increased attention as means for increasing wood production. This report describes early results and projections of the development of fertilized and irrigated *Populus 'Tristis* #1' (*Populus balsamifera* L. x *P. tristis* Frisch.) at different spacings.[1/]

Initial field plantings concentrated on close spacings because several investigators have indicated substantial tonnages of wood may be produced early in the life of dense stands (Smith and DeBell 1973, Saucier *et al.* 1972, Ek and Brodie 1975). *P. 'Tristis* #1' was chosen for the trials described here because of its rapid early growth and the availability of cuttings. Future selections of hybrids may grow faster than *P. 'Tristis* #1', but it was felt that experience gained with cultural practices, particularly spacing, fertilization and irrigation, would be useful in studies with other varieties and species.

Logistic, space, and time restrictions precluded a large number of spacing trials. Consequently, growth and competition data from the first 4 years of the trials on a limited set of field plots were used to calibrate FOREST, and individual tree based stand simulation model (Ek and Monserud 1974). In brief, the FOREST model simulates the periodic growth of individual trees as a function of their own size or condition and the competition they encounter. The approach allows the expression of individual tree response to a wide range of competition (spacings) and other cultural practices. This model was then used to develop projected yields to later ages.

CONDUCT OF THE STUDY

Cultural Practices

Hardwood cuttings 8 inches long were planted in early June 1970 on a prepared site in the Hugo Sauer Nursery near Rhinelander, Wisconsin. The cuttings were set at a depth of 6.5 inches in a 1 inch diameter hole. The soil is a sandy loam with 2 to 3 percent organic matter. The study plots were fertilized at planting and

[1/] *The research was supported by the College of Agricultural and Life Sciences, University of Wisconsin-Madison, and the USDA Forest Service.*

periodically as determined by tissue tests to maintain the levels below:

pH	6.7-7.0
phosphorous	190-200 pounds per acre
potassium	300-500 pounds per acre
calicum	11.0 millequivalents (replaceable per 100 grams of soil)
boron	2.5-3.0 pounds per acre
magnesium	3.0 millequivalents (replaceable per 100 grams of soil) minimum
manganese	20-40 pounds per acre
zinc	2-4 pounds per acre

Ammoniumnitrate was added to the soil as needed about every 3 weeks to maintain a 3.2 percent level of nitrogen in new leaf tissue. Soil moisture was maintained by irrigating at above 70 percent field capacity and weeds were controlled by the use of the pre-emergence herbicide Linuron.

Outplantings were made at three square spacings: 0.75-, 1, and 2 in plots of size 16.5, 17, and 18 feet on a side, respectively. These spacings correspond to stems per acre figures of 77,440, 43,560, and 10,890. These plantings were replicated three times (replicates I-III). Only a few seedlings died during the first year and these were replaced by similar stock.

Within each plot, a subplot was established for tree growth observations. Subplots contained 10, 30, and 50 trees for the 0.75-, 1-, and 2-foot spacings. Subplot stems were measured annually for total heights (H) and diameters (D) at the base of the root collar (0.083 feet). Only the plots from replicate III, however, were used for calibrating the FOREST model because replicates I and II were largely destroyed over the study period by harvesting for stem yield analyses and removing cuttings needed for additional plantings.

Model Calibration

The calibration of the FOREST model was described in detail by Ek and Dawson (1976); however, major aspects of this effort are noted briefly below. The most important components of the forest model are expressions for (1) potential height and diameter growth; (2) the relations between competition, realized growth, and potential growth; and (3) the relation between competitive status and the probability of survival.

Potential height growth was based on the height growth patterns of the tallest study plot stems and extrapolated to later ages by considering height growth patterns of older *Populus* trials noted in the literature. Potential diameter growth of a tree of height H was taken as the difference between its assumed open-grown diameter and the open-grown diameter of a stem of height ($H + \Delta H$) where ΔH is height growth. Open-grown diameters were developed as a function of tree height from limited data on open-grown *Populus* stems in the Hugo Sauer Nursery.

Using subplot tree height, diameter, and location data, a competition index was developed for each subplot stem for each growth period. This index was a function of the area of overlap of assumed open-grown crowns and relative subject vs. competitor tree sizes. Open-grown crown diameters were expressed as a function of tree height using the same open-grown stems used for potential diameter growth noted earlier. The competition indices and related subplot growth data were then analyzed by nonlinear regression. This step produced equations for multipliers expressing the degree of realization of potential height and diameter growth.

Survival-competition relations were developed by sorting the growth data into competition classes. The class midpoint competition index was then used as the independent variable to estimate the proportion (probability) of trees surviving through the growth period (1 year). Tree mortality was simulated by comparing the projected probability of survival with a randomly generated (uniform 0-1) threshold value. When the threshold value exceeded the probability of survival, the stem was noted as dead.

Stem Yield

Some trees were harvested from each plot each year as the basis for developing tree yield. Most of this harvesting was from replications I and II. Height and diameter were measured and the trees were physically separated into stem wood, branch wood, bark, tips (terminal buds), and leaves, and then ovendried and weighed. These data were then used as dependent variables to derive tree yield expressions of the form: component weight=f(D,H). Details of measurement procedures and the

actual weight equations developed are given in Ek and Dawson (1976).

Analysis and Projections

Yields for the first 4 years of the study were developed by applying the above weight equations to the subplot trees in replicate III.

Projections using the FOREST model were made from the initial conditions at the end of the first growing season. Projections were first made to age 4 for the 0.75-, 1-, and 2-foot spacings assuming (as was the case) no competition from beyond the plot boundaries. Then projections were made to more advanced ages for 0.75-, 1-, 2-, 4-, 8- and 12.7-foot spacings assuming a forest edge.2/ As with the actual data, yields for the projections were developed by applying tree weight equations to the projected heights and diameters of surviving stems.

RESULTS AND DISCUSSION

Stand development and yields for the actual 0.75-, 1-, and 2-foot spacing plots of replicate III are given in table 1. Table 2 gives yields for the projections and indicates the age of maximum mean annual increment (MAI).

Projection Accuracy and Reliability

Graphic comparisons of actual vs. projected average heights and diameter growth and survival patterns for the first 4 years of study for replicate III are given by Ek and Dawson (1976). Although detailed for inclusion here, in general these comparisons showed close agreement of actual and simulated results. As validation of the general approach, Monserud (1975) also found close agreement between actual stand development and 20- to 25-year projections for the FOREST model as adpated to the nine-species northern hardwood forest type in Wisconsin. As shown by Ek and Dawson in graphic form, table 2 further illustrates desired relative behavior in terms of curve shapes, inflection points, and asymptotic tendencies. The forms of the tree weight models used limit the chance of large errors in extrapolating yield projections to stems beyond the 1- to 4-year age range.

Although differences between actual and projected values do exist, it is important to note that these stand conditions posed an extreme test in terms of the wide range of competition and the large relative changes in tree size considered. Further

2/ *The plot image was replicated and shifted for competition calculations to form an eight-plot border zone around the main plot. See Monserud and Ek (1975) for a description of this methodology and implications.*

Table 1.--*Actual yields of* Populus 'Tristis *#1' study plots*

Age 1/ (years)	Average stem diameter 2/	Average total height	Live trees per acre	Dry weight per acre: Stem wood 3/	Dry weight per acre: Stem wood + branch wood
	Inches	*Feet*	*Number*	*Pounds*	*Pounds*
0.75 BY 0.75 FOOT SPACING					
1	0.2	1	77,440	251	327
2	.7	6	74,279	7,069	8,484
3	.9	10	66,178	23,557	27,132
4	1.0	12	61,238	35,213	40,390
1 BY 1 FOOT SPACING					
1	0.2	1	43,560	111	147
2	.7	6	43,560	4,578	5,686
3	1.0	11	40,299	19,726	22,782
4	1.3	14	38,491	38,300	45,131
2 BY 2 FOOT SPACING					
1	0.2	1	10,890	23	32
2	.9	6	10,890	1,768	2,326
3	1.6	13	10,487	11,193	13,770
4	2.0	17	10,083	22,636	27,567

1/ Values given for ages 2 and 3 based on observations just prior to harvest of sample stems for tree yield determination. The magnitudes of the cuts are omitted as they were all small (less than 5.1 percent of the trees).

2/ At 0.083 feet.

3/ Above 0.083 feet.

Table 2.--*Projected yields of* Populus 'Tristis #1' *plantings at various spacings*

Age (years)	0.75 BY 0.75 FOOT SPACING: Average stem diameter 1/	Average total height	Live trees per acre	Dry weight per acre: Stem wood 2/	Dry weight per acre: Stem wood + branch wood	1 BY 1 FOOT SPACING: Average stem diameter 1/	Average total height	Live trees per acre	Dry weight per acre: Stem wood 2/	Dry weight per acre: Stem wood + branch wood	2 BY 2 FOOT SPACING: Average stem diameter 1/	Average total height	Live trees per acre	Dry weight per acre: Stem wood 2/	Dry weight per acre: Stem wood + branch wood
	Inches	*Feet*	*Number*	*Pounds*	*Pounds*	*Inches*	*Feet*	*Number*	*Pounds*	*Pounds*	*Inches*	*Feet*	*Number*	*Pounds*	*Pounds*
1	0.2	1	77,440	253	330	0.2	1	43,560	106	141	0.2	1	10,890	23	31
2	.7	6	76,640	7,602	9,081	.7	6	43,183	4,908	6,082	.8	6	10,822	1,304	1,627
3	.9	9	74,880	23,358	26,863	1.0	11	42,279	19,278	22,440	1.5	11	10,688	8,523	10,689
4	1.0	11	69,760	37,674	43,387	1.2	13	40,545	33,616	39,023	1.9	16	10,621	21,521	25,983
5	1.2	12	63,840	51,588	59,758	1.4	15	37,531	47,129	54,954	2.2	20	10,553	36,365	43,658
6	1.4	14	56,080	64,673	75,406	1.6	16	34,139	60,542	71,029	2.4	22	10,150	49,368	59,400
8	1.8	16	44,320	96,685	114,699	2.1	19	29,391	[3]94,966	113,224	3.0	25	9,343	82,058	99,892
10	2.3	19	30,960	122,326	[3]147,528	2.5	21	22,684	118,106	[3]142,989	3.6	28	8,470	[3]112,525	[3]138,813
	4 BY 4 FOOT SPACING					8 BY 8 FOOT SPACING					12.7 BY 12.7 FOOT SPACING				
1	0.2	1	2,722	6	8	0.2	1	680	1	2	0.2	1	271	1	1
2	.8	6	2,705	326	407	.8	6	676	81	102	.8	6	269	33	41
3	2.1	11	2,672	3,313	4,795	2.1	11	668	828	1,199	2.1	11	266	330	478
4	3.2	17	2,655	12,828	18,283	3.9	16	663	3,981	6,462	3.9	16	264	1,588	2,578
5	4.0	24	2,638	29,729	39,896	6.1	23	659	13,057	22,775	6.3	23	263	5,481	9,983
6	4.4	29	2,621	45,409	59,898	7.4	31	655	26,673	43,514	8.8	29	261	12,743	25,155
8	5.3	35	2,554	78,724	102,893	9.4	46	642	65,402	97,839	13.1	45	258	43,183	82,801
10	6.1	39	2,436	108,972	143,053	10.5	53	630	94,590	138,856	15.1	57	253	74,573	131,300
15	7.9	48	2,083	[3]185,268	[3]248,755	12.7	64	605	[3]163,515	[3]238,470	18.2	75	243	[3]141,858	[3]234,104
20	9.5	54	1,613	222,960	305,157	14.0	70	550	190,117	278,903	19.3	80	228	156,195	256,532
25						15.2	75	508	219,128	323,447	20.0	84	223	169,138	277,161

1/ At 0.083 feet.
2/ Above 0.083 feet.
3/ Age of maximum mean annual increment.

studies on larger plots outlined later will document the accuracy of these projections and likely lead to refinements in projection methodology. For now, however, the projections given here are expected to be a valuable planning aid.

Yield Analysis

Table 1 and 2 values suggest early culmination of current annual increment (CAI). As with natural aspen stands (Ek and Brodie 1975), however, rapid growth continues past the first decade. Although the age of maximum CAI appears to depend on spacing, maximum MAI for stem wood and stem wood plus branch wood fell in the 8- to 15-year range for all spacings. Further, the dry weight yields were similar at maximum MAI except for the extreme spacings. The fact that yield curves are nearly linear in the 8- to 15-year range also suggests great flexibility in rotation ages between 8 and 15 years with little sacrifice in dry weight yields.

The 4-foot spacing appears most promising for fiber production. The MAI of 16,584 pounds per acre for stem and branch wood is approximately six times that possible from natural aspen stands as described by Ek and Brodie (1975).

These yields are promising for fiber production. However, it is also possible that the large trees developed (see table 2) may lead to consideration of thinning and other product alternatives.

FUTURE RESEARCH PLANS

Current plans are to document projection accuracy and refine the FOREST model according to observations on larger plots of *Populus 'Tristis'* over longer time periods. In particular, observations at advanced ages will aid refinement of tree component weight and product functions

Study plots of numerous other rapid growing *Populus* selections as well as *Larix* hybrids, *Pinus banksiana, Alnus,* and *Betula papyrifera* have also been extablished. Suc plots will be used early to calibrate the FOREST model. Projections and comparisons will then be made to evaluate and screen promising plant materials. Because these genotypes and/or species may respond differently to spacing, extensive use is being

made of a variation of the Nelder plot design (Nelder 1962). The actual layout varies trees spacing in two directions across the plot (fig. 1).

Figure 1.--*Sample of a variable spacing plot (four contiguous replicates) for promising* Populus *varieties. Photo taken in Hugo Sauer Nursery.*

Significant in this modeling approach is that spacing need not be uniform within plots. The FOREST model is calibrated with growing-competition rather than growth-spacing data. A range of spacings within a plot varies competition and through model calibration facilitates extrapolation of the model in subsequent projections of yields for alternative spacings. As expected, this approach is very efficient in terms of the planting stock and space required. It also incorporates and projects the effects of mortality on growth and yield.

As a supplement to simulation analyses, optimal spacing strategies may also be determined by mathematical programming. Such an approach would involve use of growth algorithms from the FOREST model in a formal optimization framework. The problem would be choosing tree coordinates on a plot so as to maximize aggregate tree growth for a period. An outline of this approach is given in Adams and Ek (1975).

In summary, as information on species, species variants, fertilization, irrigation, spacing, etc., expands, the overall modeling approach will increasingly become a focal point of the project. In this framework, the FOREST model will be the principal tool for projecting the implications of changes in cultural practices on wood production in terms of both quality and quantity.

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SOME PHYSIOLOGICAL APPLICATIONS FOR INTENSIVE CULTURE

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Every silvicultural practice employed by the forest manager is based on physiological principles. By understanding how trees grow as they do and how they respond to each silvicultural practice, the physiologist can suggest ways to increase wood yield and to improve wood quality through the deliberate manipulation of the tree's growth. To do this requires information that can only be obtained by physiological research. The results of several studies are summarized showing (a) the relation between leaf production and plant biomass production, (b) the chemical composition of wood, (c) the chemical composition of leaves, and (d) the formation of tension wood in Populus *clones grown under intensive culture. A number of desirable growth traits and tree attributes have been compiled to construct an ideotype, a hypothetical tree.*

Every silvicultural practice employed by the forest manager is based on physiological principles. Stand density management, for example, is the most powerful means available to the silviculturist for directly controlling competition and for regulating growth and yield. Site amelioration also directly affects growth and yield by improving site quality, hence crown and root development. Other silvicultural practices result in more indirect growth responses. For example, the control of crown size and shape by pruning results in a redistribution of growth on the stem, consequently an alteration in stem form and taper. Each of these silvicultural practices is effective because the trees are either stimulated to greater growth or encouraged to grow in a more desirable way. By understanding how trees grow as they do and how they respond to each silvicultural practice, the physiologist can suggest ways to increase wood yield and improve wood quality through the deliberate manipulation of selected stages of the tree's growth (Larson 1969, 1972).

It is well known that silvicultural practices achieve their effects by improving either root or crown development or the relation between them. However, because of the close inter-relation between the two systems and because root growth is so difficult to study, most research has concentrated on the crown. The leaves are the effective organs in terms of growth and the tree crown consists of an orderly assemblage of leaves. Studies have shown that the effectiveness of leaves varies with the relative age of the branch from which they arise and its position in the crown. Leaves are therefore not all alike. These leaf age-leaf position relations are basic to maximizing tree growth and yield, and they can be manipulated by cultural practices. It is the ability to manipulate these relations according to physiological principles that distinguishes intensive culture from conventional forestry. The premise on which intensive culture is based rests wholly on how efficiently, in terms of time and economic benefits, the silviculturist can manage this array of photosynthesizing leaves to produce the maximum quantity of wood of acceptable quality for a particular end use.

Even under the best of field conditions, young trees never approach their optimum

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1/ Larson, P. R. 1970. Science and the art of forestry. Belle W. Baruch Lectures, Clemson Univ., Clemson, South Carolina, March 2-6, 1970. (Unpublished.)

growth potential (Larson 1974). However, physiological research can suggest numerous possibilities for improving the environment and for selecting genotypes that can utilize it more efficiently.[2/][3/] By this approach, appropriate cultural practices can be devised for raising productivity well above the level normally attained by conventional forest management.

Physiological manipulation of a tree crop by cultural practices to attain near-maximum wood yield can lead in several directions (Larson 1969, Larson and Gordon 1969). One way would be to increase the total photosynthetic production or the leaf biomass. Under conventional forestry systems the growing site is neither efficiently utilized nor completely covered by photosynthetic organs until rather late in the rotation. By combining intensive culture with close plant spacing and a short rotation, the rapid juvenile growth of selected species can achieve most efficient use of the land. The net result of these cultural practices would be a greatly increased photosynthetic leaf surface, consequently increased dry-weight productivity.

Another way to increase plant productivty and wood yield would be to increase the effective length of the growing season because few temperate zone species utilize it completely or efficiently. Properly directed physiological research can suggest a balanced approach for culturally improving the environment and for selecting responsive genotypes that would significantly extend the growth period and increase productivity per unit land area.

Maximum dry-weight productivity does not necessarily mean maximum wood production nor does it imply that the wood will be distributed within the tree in the most desirable way. However, because of the strong relation between leaf production and wood production in young trees (Larson and Isebrands 1972), intensive cultural practices that maximize growth at close spacings will tend to concentrate growth on the stem. Again, physiological research can suggest many ways in which the high levels of photosynthetic production can be distributed within the tree to increase both the quantity and the quality of the wood produced. Specific examples to be discussed later include tension wood formation and the chemical composition of the fiber cell wall.

Research efforts of the Pioneering Unit of the North Central Station are devoted almost exclusively to the physiology of wood formation. Nevertheless, some of the research results can be applied either directly or indirectly to certain facets of intensive culture. The following research summaries fall broadly within the lines of investigation just discussed.

LEAF PRODUCTION IN *POPULUS* GROWN UNDER INTENSIVE CULTURE

By increasing the photosynthetic productivity or total leaf surface within certain limits, the dry-weight productivity of a forest crop can be increased. The most effective way to increase photosynthetic leaf surface under short-rotation, intensive-culture conditions is to plant at close spacings and thereby increase the total number of leaves produced on the area (Gordon and Bentley 1970). One method of quantifying the potential photosynthetic surface is leaf area index (LAI), which is the ratio of total leaf surface area to land area, i.e., the number of square meters of leaf area per square meter of land area. LAI can be increased by cultural manipulations designed to increase not only the number of leaves but also the size of the leaves in the tree canopy (Zavitkovski *et al.* 1974).[4/]

Trees grown on short-rotation, intensive-culture test plots by the Maximum Yield Project at Rhinelander, Wisconsin, represent examples of how dry-weight productivity can be increased by increasing LAI. Rooted cuttings of *Populus* 'Tristis' were planted at 0.2, 0.3, and 0.6 meter spacings in 4.88 meter square plots. The plots were cultivated, irrigated, and fertilized to provide near optimum growing conditions (Crist and

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2/ *Dickson, R. E. 1973. Growth and yield measurements. USDA For. Serv. In-service Workshop on Intensive Culture, Rhinelander, Wisconsin, Sept. 18-19, 1973. (Unpublished.)*

3/ *Larson, P. R. 1973. Physiological parameters of intensive culture: theoretical and applied. USDA For. Serv. In-service Workshop on Intensive Culture, Rhinelander, Wisconsin, Sept. 18-19, 1973. (Unpublished.)*

4/ *Isebrands, J. G. 1973. Biomass and primary productivity. USDA For. Serv. In-service Workshop on Intensive Culture, Rhinelander, Wisconsin, Sept. 18-19, 1973. (Unpublished.)*

Dawson 1975). After 3 years, the aboveground, dry-weight yields (without leaves) were 12.46, 11.08, and 5.95 metric tons per hectare per year (table 1) for the 0.2, 0.3, and 0.6 meter spacings, respectively (Dawson *et al.* 1976). These yields are much higher than reported for either natural or planted stands of *Populus* in the area.

Table 1.--*Above ground dry-weight yields, leaf number, and leaf area per tree for* Populus *'Tristis' grown in intensive culture plots*

Spacing	Trees per hectare	Age 3: Dry-weight yield 1/ per hecatre per year	Age 3: Leaves 2/	Age 3: Leaf area/tree 2/	Age 4: Leaf area/tree 3/
Meters	*Number*	*Metric tons*	*Number*	*Square centimeter*	*Square centimeter*
0.2 x 0.2	191,358	12.46	680	21,065	24,357
.3 x .3	107,639	11.08	832	21,959	33,614
.6 x .6	26,910	5.92	956	26,225	65,308

1/ Total above ground dry weight (without leaves). Data have been extrapolated from 4.88 square meter plots to a hectare basis (Dawson *et al.* 1975).
2/ Average 4 trees; total tree sample.
3/ Average 4 trees; 25 percent sample.

We attribute the higher productivity of plots in the present study to an increase in photosynthetic capacity resulting from an increase in LAI, a function of intensive management practices. For example, the total number of leaves and their sizes were increased by cultivation, irrigation, and fertilization. These intensive cultural practices also contributed to maintaining a high LAI throughout the growing season by prolonging retention of leaves in the lower canopy despite the close spacings. Furthermore, substantial leaf area development takes place early in the growing season in *Populus*. Therefore, the increase in photosynthetic surface occurred during that part of the growing season most critical for rapid height growth and leaf development. The largest portion of the leaf area produced in this early surge of growth was in the uppermost canopy layers where light interception was at a maximum, a necessary requirement for high productivity (Zavitkovski *et al.* 1974).

The above factors all contributed significantly to a high leaf area per tree. At the end of 3 years the total number of leaves per tree averaged 680, 832, and 956 and the total upper-surface leaf area per tree averaged 21,065, 21,959, and 26,225 square centimeters for the 0.2, 0.3, and 0.6 meter spacings, respectively (table 1). Leaf surface area continued to increase in the 4th year; the upper-surface leaf area per tree averaged 24,557, 33,614, and 65,308 square centimeters for the 0.2, 0.3, and 0.6 meter spacings, respectively. Leaf area per tree was closely related to the dry-weight production of individual trees after 4 years (fig. 1). The relation is linear because, unlike natural stands, trees growing under short-rotation, intensive-culture conditions are of the same age and have a narrow range of heights and diameters.

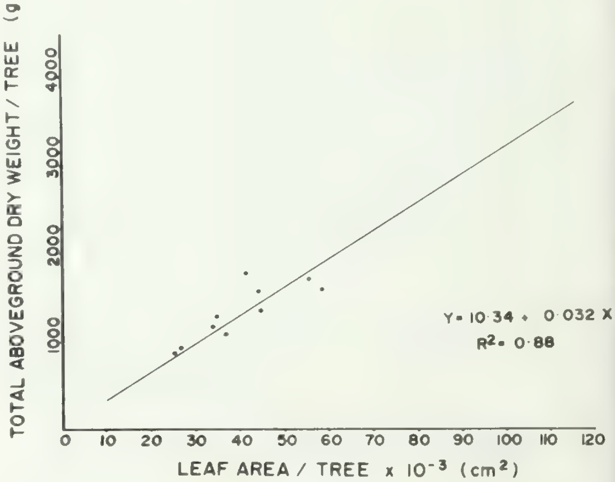

Figure 1.--*The relation between upper-surface leaf area/tree and dry-weight production in 12 4-year-old* Populus *'Tristis' trees grown under intensive culture.*

LAI was estimated by double sampling with regression (see Zavitkovski *et al.* 1974 for detailed methodology). The high leaf area per tree shown above therefore contributed to high LAI estimates for the plots. The LAI values obtained for the plots were much higher than those obtained from natural stands of *Populus* (Zavitkovski *et al.* 1974). For example, after 4 years the LAI for the plots with a 0.6 meter spacing was 17.57. This value may approach the theoretical limits for *P.* 'Tristis' in northern Wisconsin for several reasons. First, no mortality was assumed in making the calculations, and some mortality would normally be anticipated. An adjustment for mortality would lower the LAI estimates. Second, the observations were made on small plots, therefore, downward adjustments in LAI may be required, because small plots allow greater light penetration than larger plots. Consequently, leaves would be larger and leaf retention greater in the small plots, thus biasing the LAI estimates upward. Nevertheless, even after adjusting for these biases, a LAI of 12 to 15 should be expected for the 0.6 meter spacing and a LAI of 20 or more for the closer spacings. These preliminary estimates of LAI are similar to those obtained from several stands of *P.* 'Tristis' constructed by computer simulation (Promnitz and Rose 1974).

The explanation for the high LAI's and the associated high dry-weight yields undoubtedly lies with the intensive management practices. However, it should be re-emphasized that preliminary observations on small plots may not necessarily hold for larger acreages. Further research is therefore needed to quantify the effect of LAI on dry-weight production in *Populus* grown under intensive cultural practices.

CHEMICAL COMPOSITION OF WOOD GROWN UNDER INTENSIVE CULTURE

Photosynthates produced by the leaves can be distributed to other growing regions of the tree in various proportions; for example, in the allocation of photosynthate to wood development. The thickness of the fiber wall and the fiber/vessel ratio vary considerably among different *Populus* clones and hybrids. These variations are associated with changes in wood specific gravity and in the proportions of lignin, hemicellulose, and cellulose in the cell walls. Each of these factors significantly influences the yield and quality of the pulp produced. We have investigated some of this variability in wood characteristics among *Populus* hybrid clones grown under intensive culture (Dickson *et al.* 1974). The objective of the study summarized below was to examine the range of variability of several wood quality factors and to identify those clones that may have potential value in a selection program.

The wood samples were obtained from *Populus* clonal trials of the Maximum Yield Project at Rhinelander, Wisconsin. The 18 clones examined were initially selected by tree breeders in different parts of the world for fast growth, disease or insect resistance, or some other selection criterion. The clones therefore represented a wide genetic base, and when they were grown under optimum, but comparable, cultural conditions in the nursery, they exhibited a wide range of variation. In all cases, the third annual growth ring from 3-year-old shoots was sampled.

The range of properties examined varied widely among the 18 clones (table 2). For example, the width of the third annual growth ring varied considerably as did the specific gravity of its wood, although the latter was not directly related to rate of growth. Glucose, which is a measure of cellulose yield, and the remaining wood sugars, which provide a crude estimate of hemicellulose content, also varied widely. The average clonal values for the different wood characteristics, as well as their ranges, indicate that 3-year-old *Populus* wood falls within the limits of acceptability for pulp production.

Table 2.--*Wood properties and growth characteristics of 18* Populus *hybrid clones* (In percent)

Item	Average	Range
Sugars		
Glucose	63.6	60.5 - 69.2 1/
Galactose	3.0	2.5 - 3.6
Mannose	5.5	3.7 - 7.6
Xylose	26.5	22.9 - 29.1
Arabinose	1.4	0.7 - 1.7
Total	100.0	
Lignin	21.3	18.1 - 25.0
Extractives	3.3	2.2 - 4.6
Specific gravity	0.334	0.272 - 0.368
Growth rate (1973 ring wdt. (mm))	6.9	2.4 - 11.4

1/ The sugar percentages were based on total carbohydrates, while the lignin and extractive percentages were based on ovendry weight of extractive-free wood.

We selected three clones as potential candidates for intensive culture on the basis of desirable wood properties determined in this study (table 3). Other growth and yield characteristics would, of course, enter into final clonal selections.

Table 3.--*Wood properties and growth characteristics of three* Populus *clones with potential for intensive culture*

Item	*P. nigra* hybrid (5331)	Crandon (5339)	Unknown[1/] (5351)
Growth			
Height (*meter*)	5.5	5.5	5.0
Diameter (*centimeter*)	5.8	4.6	9.6
1973 Ring width (*millimeter*)	9.0	7.7	6.6
Specific gravity	0.363	0.349	0.339
Lignin (*percent*)	20.4	18.9	18.1
Extractives (*percent*)	2.2	2.8	2.9
Sugars (*percent*)			
Glucose	60.9	65.5	64.5
Xylose	28.8	26.1	26.3

1/ *Populus* sp. Parentage unknown, but contains some *P. balsamifera*.

3-year-old stems contained a high proportion of gelatinous fibers; percentages ranged from 13.8 to 38.7 in 2-year-old stems and from 14.0 to 37.5 in 3-year-old stems depending on the sampling position in the stem. After kraft pulping, gelatinous fibers were more bulky than normal wood fibers, and thus lower in collapsibility. Furthermore, the gelatinous fibers were characterized by slip planes and minute compression failures that lower the strength of the individual fibers and detract from uniformity of the pulps produced (Isebrands and Parham 1974a, b). Because of the detrimental effect of large quantities of gelatinous fibers, rotation ages of 2 to 3 years for *Populus* 'Tristis' may be too short from a utilizatio standpoint.

One important question regarding intensive culture is how growth rate affects wood characteristics. Growth rate alone appeared to exert little influence on the wood chemical characteristics of the *Populus* hybrids. Furthermore, no consistent differences in wood chemical constituents were revealed between rapid-grown cottonwood trees from plantations and slower-grown trees from natural stands (Dickson *et al.* In press). The yield differences that were present resulted either from inherent age patterns or from individual tree variation, but not from rate of growth.

TENSION WOOD IN *POPULUS* GROWN UNDER INTENSIVE CULTURE

The acceptability of the short-rotation, intensive-culture approach from the standpoint of wood utilization will depend not only upon the quantity of wood fiber produced, but also its quality. *Populus* species tend to produce large volumes of tension wood (Isebrands and Bensend 1972). The proportion and distribution of gelatinous fibers comprising the tension wood affects the uniformity and strength of the resultant pulp.

In a study of *Populus* 'Tristis' grown under intensive-culture conditions, Isebrands and Parham (1974a) found that 2- and

The above results also have physiologica implications. The high proportion of gelatinous fibers produced by *Populus* trees grow under intensive culture indicate that large quantities of photosynthate were being diverted into the production of wood with undesirable properties, namely tension wood, rather than normal wood. The trees were therefore inefficient in terms of wood production from a physiological standpoint. Also of physiological importance, tension wood formation in stems of *Populus* grown under intensive culture appeared to be strongly related to rapid growth rate rather than to lean or other tree abnormalities. This observation confirms earlier work on trees from rapidly grown cottonwood plantations (Isebrands and Bensend 1972), and suggests that rapid growth rate may produce a balance

of hormone and photosynthate within the tree to favor the formation of gelatinous fibers.

CHEMICAL COMPOSITION OF LEAVES GROWN UNDER INTENSIVE CULTURE

Research on the utilization of foliage has been given little consideration within the United States (Keays and Barton 1975). With present methods of whole tree utilization, leaves, or leaves plus bark, constitute a costly chip contaminant. However, there are several potential uses of foliage that might make its separation and utilization profitable. One of these might be a protein concentrate for either human or livestock consumption, depending on its recovery grade and purity (Stahmann 1968, Pirie 1971). Another use might be as a livestock feed in the form of "muka" (Keays and Barton 1975). Muka, as prepared in the USSR, is an animal feed and vitamin supplement made of finely ground foliage, bark, and small branches. Depending on the amount of branch and bark material in the mix, muka can be a satisfactory substitute for an equal weight of alfalfa or clover meal. If the protein or nitrogen content of the foliage is low, urea can be added during the processing. The use of tree foliage as a partial replacement for conventional animal feeds appears to offer an immediate gain from research and the greatest potential for the utilization of what is at present a waste product.

As part of the information necessary for utilization of foliage from trees grown under intensive cultural conditions, the major chemical constituents were examined in leaves from essentially the same *Populus* hybrid clones that were examined for wood chemical characteristics.[5/] In addition, leaves from 2-year-old trembling and bigtooth aspen sprouts and from 3-year-old nursery-grown green ash and silver maple saplings were examined for comparison.

Although all of the trees except bigtooth and trembling aspen were grown in the same area of the nursery and received the same amounts of fertilizer and water, there were considerable differences in the various chemical fractions (table 4). For example, total nitrogen (N) of the *Populus* leaves ranged from 2.1 to 3.9 percent on a dry-weight basis. Leaves from the unfertilized trembling aspen sprouts and the green ash and silver maple saplings contained lower average amounts of total N and protein than the *Populus* clones.

The extracted protein and soluble amino acid fractions provide estimates of the food value of leaves, particularly if used for human consumption or for high quality livestock-feed supplements. However, much of the protein is not extracted by the methods used to isolate these fractions. A better indication of the potential for muka production is therefore crude protein, which is calculated by multiplying total nitrogen percent by 6.25. The average crude protein value for the *Populus* leaves was 19.5 percent of the total dry weight. This value compares favorably with that found in alfalfa, one of the major forage crops produced in the United States (Kohler and Bickoff 1971).

The carbohydrate fractions of forage also provide important nutritional benefits, particularly to ruminants. Total nonstructural carbohydrate (TNC) is a common measure for estimating carbohydrate food value of forage; it consists of the total soluble sugars plus starch. TNC averaged about 2 percent of the total leaf weight in both the *Populus* hybrids and the other fast-growing trees.

Leaves from four clones with potential for muka production (table 5) contained high levels of total N, protein, and TNC. It is evident from these data that *Populus* leaves have a high potential as an animal-feed supplement.

SUGGESTED APPLICATIONS OF PHYSIOLOGICAL RESEARCH

The foregoing study summaries suggest several ways for improving certain growth and yield characteristics of *Populus* when grown under short-rotation, intensive-culture conditions. The characteristics studied are not necessarily those of most interest to the silviculturist. Many growth and yield traits must be considered when selecting the species or clones for a given set of end-use requirements. However, the greater the data base available to either the silviculturist or the geneticist, the better he can make his initial selections and improve on subsequent ones destined for future rotations. The tree physiologist can contribute

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5/ Dickson, R. E., and P. R. Larson. Unpublished data on file at the Institute of Forest Genetics, North Central Forest Experiment Station, Rhinelander, Wisconsin.

Table 4.--*Major chemical fractions from leaves of* Populus *hybrid clones and from other trees with potential for intensive culture plantations*

(In percent, dry weight)[1/]

Chemical fraction	Nursery grown *Populus* hybrids[2/]		Other fast-growing trees[3/]	
	Average	Range	Average	Range
Total N	3.1	2.1 - 3.9	2.4	2.0 - 2.8
Crude protein (N x 6.25)	19.5	13.4 -24.1	15.3	12.6 -17.4
Extracted protein	3.2	1.0 - 5.9	2.2	1.4 - 3.3
Soluble amino acids	0.16	0.09 -0.24	0.15	0.05 -0.21
Reducing sugar	8.7	3.6 -12.4	8.8	6.0 -10.9
Total soluble sugar	16.4	9.6 -21.4	16.1	10.6 -22.1
Total nonstructural carbohydrates (TNC)	21.8	16.0 -26.5	21.2	19.0 -23.8
Starch (TNC-total sugar)	5.4	2.9 - 7.1	6.3	1.4 -23.8

1/ The data do not total 100 percent because not all chemical fractions are included.

2/ Recently matured leaves from 21 *Populus* hybrids growing in the Maximum Fiber Yield Project clonal nursery at Rhinelander, Wisconsin.

3/ Three-year-old nursery-grown green ash and silver maple saplings, and 2-year-old trembling and bigtooth aspen sprouts from natural stands.

Table 5.--*Leaf chemical fractions of four* Populus *hybrid clones with potential for "muka" production*

(In percent, dry weight)

Chemical fractions	*P. candicans x P. berolinensis* (5263)	*P. betulifolia x P. trichocarpa P. nigra* (5331)	*P. euramericana* (cv.Wisconsin 5) (5377)	Unknown[1/] (5351)
Total N	3.9	3.8	3.5	3.4
Crude protein (N x 6.25)	24.1	23.6	21.8	21.5
Extracted protein	3.5	4.6	5.9	4.1
Soluble amino acids	0.13	0.24	0.21	0.17
Reducing sugars	11.1	6.6	6.8	8.7
Total soluble sugar	19.6	20.2	16.4	13.4
Total nonstructural carbohydrates (TNC)	24.0	23.1	22.0	17.4
Starch (TNC-total sugar)	4.4	2.9	5.5	4.0

1/ *Populus* sp. Parentage unknown, but it contains some *P. balsamifera.*

to this data base, explain and interpret sources of variation in selected growth and yield traits, and recommend traits that show promise for future improvement. By means of an integrated research program involving the efforts of silviculturists, physiologists, and tree breeders, the characteristic and requirements for an ideal tree might be proposed and the best approaches for achieving them prescribed.

The ideal tree for intensive culture would produce the maximum quantity of usable wood in the shortest possible time. The ideal tree can be easily visualized by constructing an "ideotype" (Donald 1968), a biological model that incorporates a number of desirable growth traits and tree attributes into a hypothetical tree. An ideotype, proposed for cottonwood, based on selected physiological and morphological attributes is shown below. A tree ideotype with a slightly different set of attributes was prepared by Dickmann (1975). Although the ideal, or perfect, tree is perhaps unattainable, the ideotype can provide a theoretical goal for the researcher and a practical one for the silviculturist.

COTTONWOOD IDEOTYPE

Shoot Growth

Rapid juvenile growth to fully and quickly occupy site at close spacings.
Rapid growth early in season to take advantage of growing season and site.
Slower shoot growth later in season to minimize vessel formation.
Relatively short internodes to maintain stem stability and divert more photosynthate to cambial growth.
Cambium should remain active until late in season for maximum wood formation.
Weak competitor so that all stems survive at desired spacing and for uniformity at harvest.

Leaves

Medium to large size to maximize photosynthesis per unit leaf area.
Well distributed on stem with petioles erect if leaves are small, pendant if large, to maximize light interception.
High photosynthetic efficiency.
Long leaf retention under low light and stress until late in season to maximize fiber formation; i.e., light tolerant with low compensation point.

Branches

Short and sparse to tolerate high stand density and to maximize dry matter distribution to stem.
Ideally, no branches, but some may be required to fill lower canopy and to maintain stem stability.

Stem

Small pith.
Straight, thick stem to concentrate wood, minimize pith and bark volumes and tension wood formation.

Bark

Thin bark.
Low stone cell, high fiber content if pulped.
Good bark slippage if removed before pulping.

Roots

Good balance between root and shoot.
Good nutrient and water uptake.
Good coppicing ability, but sparse coppice per shoot.
Ability to withstand repeat harvesting.

From Larson[3/]

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CONTROLLED-ENVIRONMENT SELECTION OF <u>POPULUS</u> CLONES[1]

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Short-term, controlled-environment growth was used to select fast growing Populus *clones. The selection technique was a ranking process using leaf weight, stem weight, and total height as indicators of growth potential. Twenty-five clones were tested, and 14 clones were recommended for field trials.*

In north-central United States, *Populus* clones are being examined for intensive silviculture because of their rapid growth, ease of propagation, and high utility for a variety of wood fiber products (Schreiner 1970, Cram 1960, Larson and Gordon 1969, Dawson and Hutchinson 1973). Because more *Populus* species and variants are available than can be reasonably field-tested, researchers must decide what material should be used in breeding programs and field trials. A technique for rapidly selecting superior clones, a key element in intensive silviculture, must be devised.

A study was designed to select clones for use in field and laboratory studies by Iowa State University and the North Central Forest Experiment Station, USDA Forest Service. Several clones, previously identified as having rapid juvenile growth, were compared under three differenent environmental conditions. Different environments were used because the performance of a clone under several test environments may be a better guide to performance in the field than the performance of the clone under any one test environment.

METHODS

The 25 *Populus* clones used in this study were chosen from those gathered by the Maximum Yield Project of the North Central Forest Experiment Station for possible use in field trials (table 1). No particular mix of parentage or origin was chosen; for some clones (e.g., 5258), no reliable information on lineage was available. Rather, I wanted to compare clones as they would normally become available for field use; that is, from a wide variety of sources, often with little detailed genetic information. (Clones 2 and 19 probably are the same; this was discovered after all analysis of the data was completed.)

In all three environments, apical cuttings rooted under mist were grown in 2-gallon plastic pots containing a 3:1 Jiffy-Mix:Perlite artificial substrate.

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Table 1.--Populus *clones included in this study*

Clone numbers: Iowa State University	Clone numbers: North Central Forest Experiment Station	Name and parentage
1	4877	*Populus alba* L.
2	4878 (5327)	*Populus* x *euramericana* Guinier *deltoides* x *nigra*
3	4879	*Populus* x *euramericana* Guinier
4	5258	*Populus sp.*
5	5262	*Populus candicans* Ait. x *Populus berolinensis* Dipp.
6	5263	*Populus candicans* Ait. x *Populus berolinensis* Dipp.
7	5264	*Populus deltoides* Marsh. x *Populus plantierensis* Schneid.
8	5265	*Populus deltoides* Marsh. x *Populus trichocarpa* Torr. et Gray
9	5266	*Populus deltoides* Marsh. x *Populus trichocarpa* Torr. et Gray
10	5267	*Populus deltoides* Marsh. x *Populus caudina*
11	5271	*Populus charkoviensis* Schroed. x *Populus deltoides* Marsh.
12	5272	*Populus nigra* L. x *Populus laurifolia* Ledeb.
13	5321	*Populus* x *euramericana* Guinier
14	5322	*Populus* x *euramericana* Guinier
15	5323	*Populus* x *euramericana* Guinier
16	5324	*Populus* x *euramericana* Guinier
17	5325	*Populus* x *euramericana* Guinier
18	5326	*Populus* x *euramericana* Guinier
19	5327 (4878)	*Populus* x *euramericana* Guinier
20	5328	*Populus* x *euramericana* Guinier
21	5331	*Populus betulafolia* Dipp. x *Populus trichocarpa* Torr. et Gray
22	5332	*Populus betulafolia* Dipp. x *Populus trichocarpa* Torr. et Gray
23	5334	*Populus deltoides* Marsh. x *Populus trichocarpa* Torr. et Gray
24	5260	*Populus tristis* Fish. x *Populus balsamifera* L.
25	5377	*Populus* x *euramericana* Guinier, "Wisconsin No. 5"

Pot moisture was maintained near field capacity by frequent watering, and nutrient level was kept high by weekly fertilization with a commercial water-soluble fertilizer (20-20-20) with an added micronutrient mixture. Pots were thoroughly flushed with water every 2 weeks to prevent salt accumulation.

These conditions are not, of course, known to be optimum for all clones included in the study. They have, however, produced consistently greater growth for *Populus* than any other conditions we have tried, including aeration, complete-nutrient-solution, or hydroponic culture.

The three environments, differing primarily in light quality, light intensity and temperature, were:

Greenhouse I
- Growth period: 8 weeks (April 12 to June 7).
- Photoperiod: 18 hours (part of which was artificial light).
- Temperature: variable (with the thermostat set at 21°C).

Greenhouse II
- Growth period: 8 weeks (May 17 to July 12).
- Photoperiod: 18 hours (part of

which was artificial light).
Temperature: variable (with the thermostat set at 21°C).

Growth Chambers
Growth period: 6 weeks.
Photoperiod: 18 hours (in Percival, Model PT-80 growth chambers).
Temperature: 25°C day and 15°C night.

The growth-chamber environment was the least variable, with little variation in photoperiod, light intensity, and temperature. Greenhouse II had a much higher temperature and a longer natural light photoperiod than did Greenhouse I. Light intensities were highest in Greenhouse II because of seasonal changes in solar position.

The plants were placed on benches in the greenhouse and in growth chambers at random.

Growth rates were determined from weekly total leaf counts and total height measurements (cm), beginning with initial measurements when the rooted cuttings were removed from the propagation bench. Leaf ovendry weight (g) and stem ovendry weight (g) were determined at the end of the growth period.

RESULTS

Growth

Clones varied greatly in all growth characteristics measured, but showed some consistency when compared across the three test environments. Total height and dry weight of leaves and stems showed large differences among clones and environments (tables 2, 3, and 4).

When all clones were pooled, mean leaf and stem dry weight and total height were all greatest in Greenhouse II (table 5). The greater total solar radiation available in this environment, due to longer natural daylight periods, greater average light intensity during the longer days, and a greater proportion of clear days during the 8-week growth period, all contributed to greater growth in this environment. The growth chamber means were smaller than those of either greenhouse environment,

Table 2.--*Any two means not next to a common line are significantly different (Duncan's new multiple range test for significant differences)*

(In grams)

Greenhouse I		Greenhouse II		Growth Chambers	
Clone	Mean	Clone	Mean	Clone	Mean
3	18.80	4	32.49	24	7.96
4	18.01	23	31.89	4	6.71
5	17.58	18	31.28	18	6.68
9	17.32	25	30.88	5	6.65
23	15.40	9	27.97	25	6.62
8	14.73	3	27.25	3	5.95
15	14.57	17	24.81	9	5.91
18	14.42	15	23.82	1	5.83
21	14.31	7	23.54	6	5.78
16	14.19	5	23.16	17	5.55
17	14.14	20	22.78	21	5.46
12	14.13	8	22.19	23	5.33
22	13.52	6	20.62	15	5.32
7	13.46	1	20.23	7	4.95
25	12.64	12	19.51	12	4.94
6	12.10	2	18.88	22	4.91
24	12.01	16	18.11	8	4.77
19	11.54	14	18.08	13	4.66
14	11.35	19	17.34	2	4.47
2	10.35	22	17.26	16	4.30
13	10.15	21	16.43	19	3.98
20	8.39	24	15.51	20	3.38
10	6.91	10	10.47	14	3.27
11	6.87	13	10.25	11	3.20
1	6.12	11	7.38	10	2.57

Table 3.--*Any two means not next to a common line are significantly different (Duncan's new multiple range test for significant differences)*

(In grams)

Greenhouse I		Greenhouse II		Growth chambers	
Clone	Mean	Clone	Mean	Clone	Mean
9	32.49	23	54.88	9	22.37
8	29.71	9	49.27	23	19.84
23	29.59	8	45.46	8	19.52
4	27.38	7	43.76	4	19.02
3	27.28	4	42.99	25	18.63
7	25.36	15	39.22	6	18.37
15	24.36	18	39.01	18	17.75
5	24.33	17	37.90	17	17.40
17	23.86	25	37.27	5	16.96
18	21.75	3	36.34	1	16.86
16	21.50	14	34.63	7	16.77
14	21.32	5	32.82	15	16.76
21	21.22	20	31.44	12	16.06
12	20.44	1	31.23	21	15.88
20	20.41	2	30.69	24	15.51
19	18.42	19	29.56	3	15.18
22	18.31	12	28.73	20	14.85
2	18.04	6	28.59	16	14.83
13	17.95	16	28.26	13	14.28
25	17.93	21	26.14	2	13.74
24	17.40	24	22.07	22	13.60
6	16.94	22	21.80	19	12.44
10	13.00	10	18.59	14	12.09
1	12.85	13	17.74	10	10.33
11	9.91	11	11.45	11	7.90

Table 4.--*Any two means not next to a common line are significantly different (Duncan's new multiple range test for significant differences)*

(In centimeters)

Greenhouse I		Greenhouse II		Growth chambers	
Clone	Mean	Clone	Mean	Clone	Mean
5	181.2	23	192.8	5	94.8
3	163.4	5	188.8	6	86.9
9	158.2	9	180.0	24	85.5
22	157.6	3	172.1	3	82.1
6	156.4	18	171.6	1	81.9
23	155.9	7	170.6	12	80.7
12	151.0	25	170.4	2	79.7
19	144.0	6	170.2	9	79.0
15	141.8	17	169.5	18	78.9
8	141.4	22	167.7	23	78.6
16	140.8	4	166.6	22	78.1
4	140.4	12	164.9	7	77.0
17	137.9	15	160.6	15	76.5
2	136.8	2	160.0	25	75.6
7	135.4	8	156.4	17	75.2
25	134.2	21	154.2	4	75.1
18	130.5	1	153.8	21	74.9
24	124.4	16	147.9	19	72.8
13	121.8	19	142.6	8	71.9
1	120.9	24	134.7	16	65.5
14	117.5	14	133.4	13	65.4
21	115.2	20	124.6	11	64.3
10	110.3	10	118.7	10	58.6
11	104.9	11	112.6	14	55.6
20	97.9	13	108.8	20	49.9

Table 5.--*Means and ranges for leaf and stem weight and total height for all clones pooled in each environment*

Item	Green-house I	Green-house II	Growth chambers
LEAF WEIGHT (GRAMS)			
Mean	20.68	32.79	15.79
High	32.49	54.88	22.37
Low	5.82	11.45	7.90
Variance	39.92	55.12	15.46
STEM WEIGHT (GRAMS)			
Mean	12.54	21.29	5.18
High	18.80	32.49	7.96
Low	3.04	7.38	2.57
Variance	15.10	23.69	2.72
TOTAL HEIGHT (CENTIMETERS)			
Mean	134.7	155.7	74.3
High	181.2	192.8	94.8
Low	82.5	98.8	49.9
Variance	25.79	219.28	68.24

primarily because of the shorter growth-chamber growth period (6 rather than 8 weeks), but also because of lower growth-chamber light intensities. Because total photoperiod was the same in all three environments, photoperiodic reactions should not have caused differences in growth among environments.

Within each environment a high rank for one variable did not necessarily indicate high rank for other variables. Moreover, clonal ranking based on individual variables or sums varied from environment to environment. Clearly, further analysis beyond simple ranking and summing was necessary to indicate clearly which clones, in fact, had the greatest juvenile growth potential and stability across environments. Therefore, growth variables for clones within environments were subjected to analysis of variance, and differences among clones (for each growth variable in each environment) were examined by use of Duncan's new multiple-range test (tables 2, 3, and 4).

Greenhouse II produced the greatest number of significant differences among clones in stem weight as well as the greatest stem weights (table 2). Seven clones produced significantly greater mean stem weight regardless of environment. These seven clones (3, 4, 9, 17, 18, 23, and 25) may be regarded as consistent producers of heavy stems across all environments.

Clones producing the greatest total leaf weight were also consistent for all three environments (table 3). As with stem weight, Greenhouse II produced the greatest number of significant differences. Three clones, 8, 9, and 23, constituted the top group. Two of these (9 and 23) also were in the top group for all environments in stem weight production.

Total height analysis presented a somewhat different picture. Greenhouse I produced the greatest number of significant differences in total height (table 4). But, of the six tallest clones in Greenhouse I, only three (3, 9, and 23) appeared in the group showing consistently greatest stem weight, and only two (9 and 23) appeared in the group showing consistently greatest leaf weight. Thus, high potential for top weight production is not necessarily related to high potential for elongation growth.

Leaf number increased roughly with time; therefore, regressions of leaf number on time were examined to see if rate of leaf production, as indicated by the slope of this regression line, was an indicator of final weight or height or both. If it were, it might be possible to reduce or eliminate destructive measurement. Again, Greenhouse II produced the greatest slopes, reiterating the generally better growing conditions in this environment. There was little consistency, however, between leaf production and final weight and (or) height. For example, clone 23, one of the best performers in terms of stem and leaf weight and height growth, had one of the lowest rates of leaf production.

DISCUSSION

Short-term juvenile production of photosynthate is the trait most desired for the clones to be used in larger field trials. If distribution of the photosynthate does not change during the first few years of growth of these clones, selection can be based entirely on stem weight production. But because distribution of photosynthate may change, total height growth of the clones must also be considered. Therefore, recommendations for clones to be used in field trials must be based on both stem weight and total height. The leaf/stem ratio also is an important criterion for selection, but not as critical as the absolute value of the photosynthate produced. In these data, a trend of more favorable leaf/stem ratio is discernible for the faster growing clones.

Thus, our initial selection of clones for field trials is based on ranking of total height and stem weight for the three environments. The following clones are recommended for field trials: 2, 3, 4, 5, 6, 7, 9, 12, 15, 17, 18, 22, 23, and 25. This type of selection scheme will separate clones that grow well in height and stem weight under all three environments. Further screening must be done for disease and insect resistance and fiber quality before making final selection of clones for use in intensive culture systems.

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RAPID SELECTION TECHNIQUES FOR IDENTIFYING SUPERIOR CLONES[1]

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Techniques for selecting fast-growing Populus *clones use physiological and morphological variables as indicators of field performance. The selection indices can be a valuable tool in preliminary work where large numbers of clones must be considered.*

Although agricultural productivity has been greatly increased over the past several decades, there has been little concomitant increase in our ability to produce greater yields per-acre of wood products. The need for new approaches to the production of wood fiber has been stated (Larson and Gordon 1969b, Gordon and Bentley 1970, White 1973), and the development of comprehensive methods for producing high per-acre yields of wood fiber under intensive cultural conditions has been underway for some time (McAlpine *et al.* 1966).

The current emphasis is to increase wood fiber yield to aid conventional wood-using industries, but there is some interest in woody plants as a source of fuel and protein (Szego and Kemp 1973, Grantham and Ellis 1974, Pirie 1969). Eventually, wood will be regarded as a chemical raw material. When this occurs, current quality criteria such as fiber length and wood strength will be less important, the definition of "superior genotype" will change, and more emphasis will be placed on maximum dry-mass production. Techniques for the rapid selection of superior clones will be a key element in intensive silviculture.

As has been pointed out in the previous paper in this proceedings, one of the most promising candidates for maximum fiber production management in north-central United States is the genus *Populus*. The chances of successful early selection are enhanced by genetic consistency of clonal material, knowledge already accumulated about the culture of poplar, and the well defined cultural conditions and relatively short rotations used in intensive silviculture (Larson and Gordon 1969b). Intensive silviculture improves chances of successful selection because environmental and genetic variation, and time, the principal saboteurs of growth-predicting correlations, are much reduced.

If controlled environment and physiological indicators can be used to select genotypes capable of rapid growth, large field trials could be greatly reduced in size, with savings in time, effort, and money. Currently, our cooperative effort with the North Central Forest Experiment Station is concentrating on the development

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of comprehensive techniques for rapid screening by using controlled-environment growth studies (Wray 1974, Zuuring 1975) detailing procedures from propagation to data analysis and interpretation.

Physiological analysis and field experiments also play an important role in our program to develop selection methods. Physiological criteria could be used by themselves to predict field performance. We think, however, that combining physiological criteria with measurements of growth in controlled environments will predict field performance best (fig. 1).

The major objective of our program is to identify clones with combinations of characteristics that result in maximum dry weight yield in the field. Our approach involves the construction of indices based on controlled-environment growth and simple physiological measurements that will accurately predict field performance under specific cultural regimes. Our approach has been to consider clones that differ markedly in juvenile growth rate and to examine them for differences in the physiological processes and morphological characteristics that we believe determine productivity (Gordon 1975). At the same time, we are studying growth of the same clones in a variety of controlled and field environments and determining what combinations of environment and growth variables best predict field performance (Hennessey and Gordon in press).

PREDICTIVE VARIABLES

If predicting growth is the only objective, variables correlated only with growth rate can be used, but we believe that there are sound reasons for working with morphological characteristics and physiological processes that are causally related to growth and yield. Not only are such variables likely to be good predictors, but increased knowledge will point the way to efficient yield improvement in the future.

Physiological Variables

On the basis of previous knowledge about tree and stand growth, we think that three broad areas of tree physiology are most likely to contain predictive variables:

1. Photosynthesis and respiration--the processes directly determining net carbon fixation (which is dry-weight growth if the small percentage of dry weight due to mineral uptake is disregarded).
2. Nitrogen uptake and metabolism--the processes responsible for the utilization of the nutrient most often limiting tree growth.
3. Hormone metabolism--the basic system of meristem coordination and control.

Each of these physiological areas can be described by many measured variables,

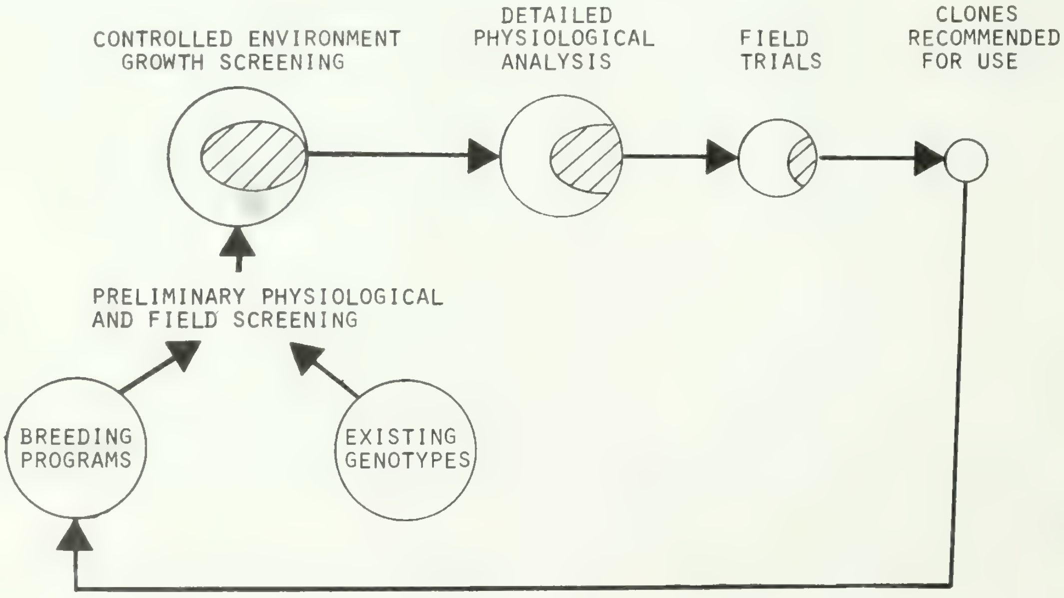

Figure 1.--*Proposed system for use in screening* Populus *clones.*

and measurements can be made at different levels of organization (subcellular, cellular, tissue, organ, tree, or stand) and at different places in the biochemical chain, linking information stored in the genome to form and function (nuclear acids, individual enzymes, systems of enzymes, fluxes of substrates, and products). If thousands of genotypes must be screened rapidly, physiological measurements must be simple, inexpensive, and fast. We have thus concentrated on measurements of gas exchange and specific enzymes at the tissue and organ level while being careful to relate measurements to whole tree and stand measures of growth.

Variables we have measured include:

1. Net photosynthesis, photorespiration, and dark respiration (Domingo and Gordon 1974, Dickmann *et al.* in press) as well as the related measures of leaf physiological state and activity, CO_2 compensation point (Dickmann and Gjerstad 1973), stomatal diffusion resistance, incorporation of ^{14}C-labeled photosynthate into leaf protein (Dickmann *et al.* in press), and glycolate oxidase activity (Gjerstad 1975).
2. Peroxidase activity, both as total activity in crude extracts and as isoenzymes resolved in acrylamide gel electrophoresis (Gordon 1974, Wolter and Gordon 1975, Wray 1974).
3. Nitrate reductase activity (Dykstra 1974, Fasehun 1975).

Morphological and Growth Variables

Morphological and growth variables also were used as indicators of growth potential in our studies. Several growth studies under controlled environment (Wray 1974, Hennessey and Gordon in press, Zuuring 1975, Dykstra 1974, Fasehun 1975) and field environment (Rose and Promnitz 1975) have given us information about growth potential of several *Populus* clones.

Morphological and growth variables that we have measured include:

1. Short-term measurements of growth potential--experiments under uniform growth-chamber environment plus studies during several times of the year under the more variable greenhouse environment.
2. Field trials--clonal densities studies at Ames, Iowa, and Rhinelander, Wisconsin.
3. Crown geometry--leaf orientation and shape as related to optimum crown arrangement for entrapment of solar energy.

RESULTS

Initial growth studies (Wray 1974, Zuuring 1975) examined a large set of *Populus* clones to determine potential growth differences (fig. 2). From this set, a subset of *Populus* x *euramericana* clones was selected that exhibited different growth rates and response to environments (table 1). Clone 5321 was slow growing, while clones 5323, 5326, and 5377 grew consistently faster (table 2). Primary emphasis of further experiments dealing with controlled-environment growth, physiological characteristics, and field performance concentrated on this subset of clones.

Although the subset of clones is small, it seems that controlled-environment growth studies can identify genetic potential for growth under certain field conditions (fig. 3). Better controlled-environment growth conditions will, however, improve the differentiation among clones and increase predictive abilities (Wray 1974, Hennessey and Gordon in press).

Several studies have attempted to relate clonal growth potential to a wide variety of physiological and morphological variables (table 3). These clones were found to differ in photosynthetic properties, leaf nitrate reductase activity, peroxidase activity, leaf angles, and leaf density. Consideration of variables singularly, however, tends to obscure the issue of growth performance. Individual variables measure only a single component in a large system that results in growth. When many physiological measures are combined through multivariate analysis, discrimination among clones often is improved. For example, when eight photosynthetic variables are combined into two canonical variables, clear discrimination between clones 5321 and 5326 can be made (fig. 4).

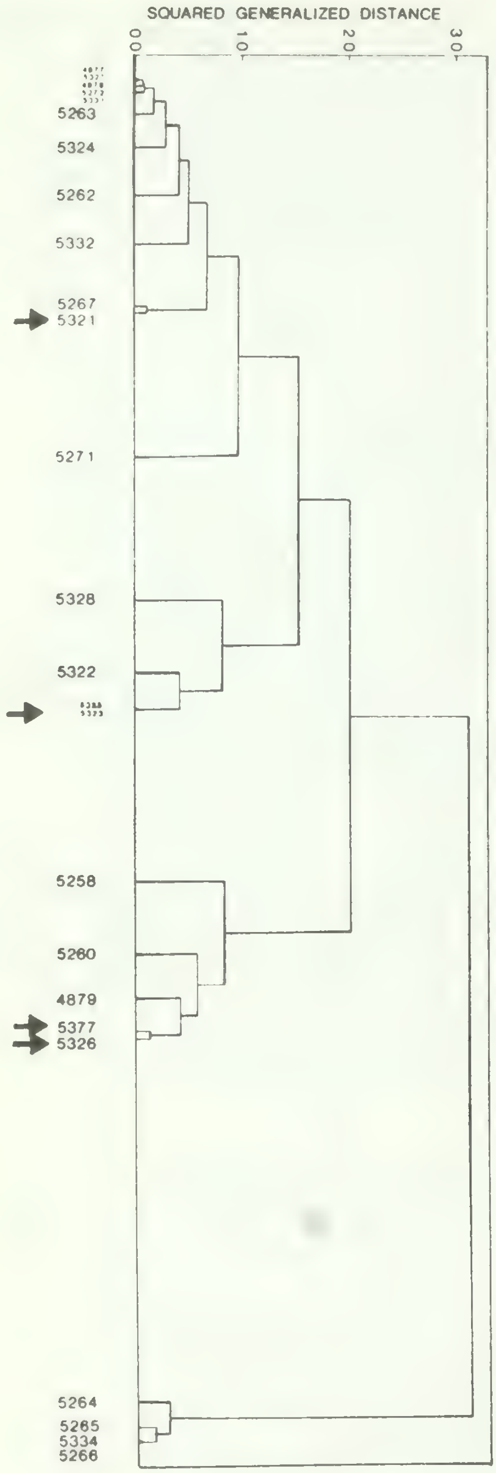

Figure 2.--*Dendrograph displaying the results of a cluster analysis performed on the generalized squared distances between 25 clones based on stem dry weight, leaf dry weight, and height.*

Table 1.--*Parentage of the contrasted clones*

Clone	Sex	Parentage			Clone name
5321	female	Populus x euramericana (Dode) Guinier			Negrito de Grancda
5323	male	do.	do.	do.	Canda Blanc
5326	male	do.	do.	do.	Eugenii
5377	male	do.	do.	do.	Wisconsin No. 5.

Table 2.--*Total stem dry weight of selected* Populus *clones grown under various environmental conditions*
(In grams)

Clone	Age		
	6 weeks	8 weeks	2 years
5321	4.7	10.2	341.6
5323	5.3	19.2	487.3
5326	6.7	22.8	594.1
5377	6.6	21.8	500.9

Alternative sets of variables also can be used under specific conditions for prediction. For example, clone 5321 grows slowly but has a high rate of photosynthesis This is partly because clone 5321 is somewhat shade tolerant (Fasehun 1975). Plants with high peroxidase activity may have the potential for faster growth because of the relation between peroxidase and lignification (Siegel 1956). Nitrate reductase level may indicate potential for utilization of nitrogen by the plant.

At this preliminary stage in developmen of selection techniques, it may be best to rely on simple growth measures because growth is an expression of the combination of all morphological and physiological variables. We believe, however, that combining physiological criteria with measures of growth in controlled environment will give the best predictions of field performance. Growth rate under optimal conditions is not the only property we wish to select for. We are now beginning studies aimed at discovering early selection criteria for disease and insect resistance and response to nitrogen and water. It has been suggeste that early selection for wood-quality criter such as fiber-to-vessel ratio, could be carried out successfully (Larson and Gordon 1969a), particularly if the relation betwee growth rate and wood formation is better understood.

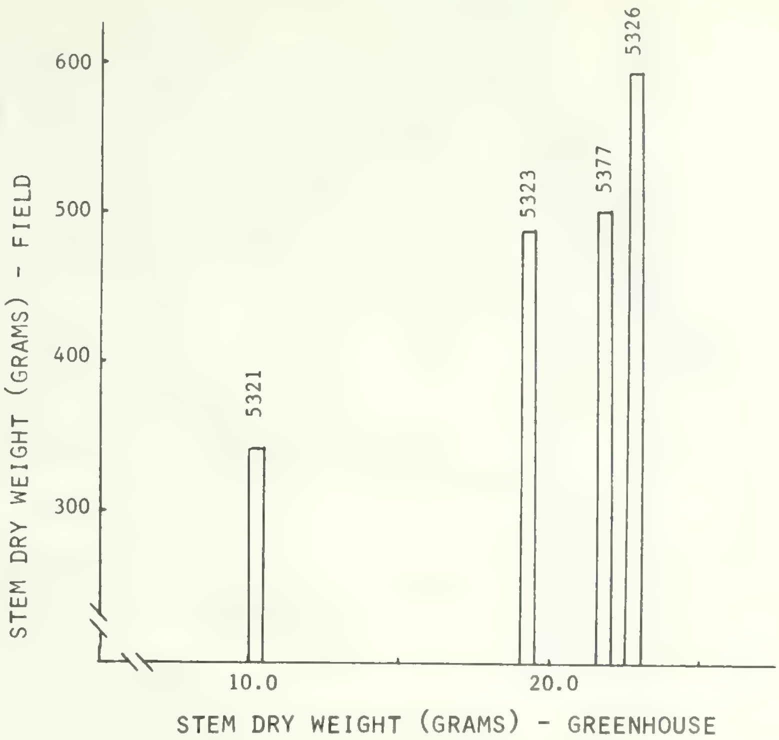

Figure 3.--*Comparison of average dry weight of clones grown in greenhouse versus average dry weight of clones grown in the field for 2 years.*

Table 3.--*Physiological and morphological variables of the contrasted clones*

Clone	Physiological variables				Morphological variables			
	Dark respiration: mg CO_2 $hr^{-1}dm^{-2}$ LPA 10	Photosynthesis: mg CO_2 $hr^{-1}dm^{-2}$ LPA 10	Nitrate reductase: NO_2 hr^{-1} g^{-1} LPA 10	Total peroxidase: units g^{-1}(dry wt) internode	Leaf area/weight: cm^2/g	Leaf angle: LPA 10 Long	Leaf angle: LPA 10 Short	Stem/leaf dry weight ratio
5321	0.97	11.94	3.2	0.88	100.3	83	51	0.33
5323	.82	9.77	10.4	1.10	94.0	112	59	.35
5326	1.31	13.91	4.2	1.03	115.2	92	41	.38
5377	1.33	11.00	5.5	1.06	110.8	95	39	.35

CONCLUSIONS

Early selection techniques for the identification of "superior" clones will form an important component of tree breeding programs and intensive silviculture. Ultimately, selection criteria could be based solely on physiological variables

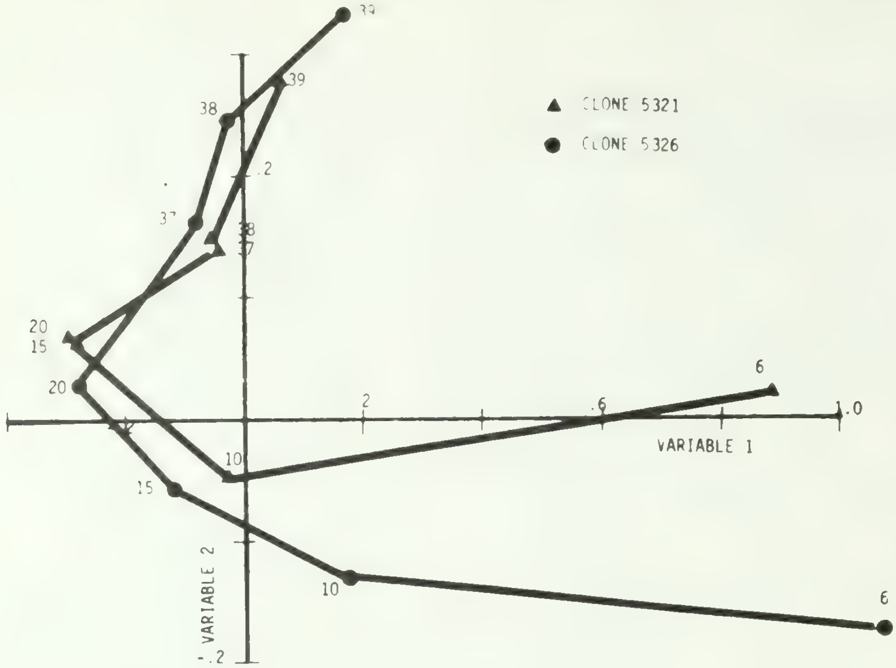

Figure 4.--*Multivariate plot of canonical variables 1 and 2 for leaves of different ages for clones 5321 and 5326. The canonical variables are functions of photosynthesis (21 percent O_2), photosynthesis (2 percent O_2), dark respiration (2 percent O_2), apparent photorespiration (21 percent O_2), apparent photorespiration (2 percent O_2), CO_2 compensation concentration, and diffusion resistance.*

measured at the cellular level. Our success with controlled-environment studies, however, indicates that, for the best prediction of field performance, some combination of physiological criteria with measures of growth will be necessary. Although such screening techniques may be subject to error in classification of growth potential, they can provide, in conjunction with small-scale field observations, a valuable tool in preliminary work in which large numbers of clones must be considered.

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BIOMASS STUDIES IN INTENSIVELY MANAGED FOREST STANDS

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Whole tree utilization and pulping systems require that forest products be measured in weight rather than in volume. Sampling methods, based on destructive tree sampling and allometric relations are outlined for determination of standing biomass and production of genetically improved pulp tree species. Maximization of biomass production will be achieved by optimizing various plant and environmental factors including leaf biomass, spacing, soils moisture, and nutrients. Biological optimum rotation age will be determined for each species grown in plantations at various spacings. Efficiency of solar energy conversion in the intensively managed stands will be estimated from their biomass production and energy content (obtained by calorimetry) of the tissues.

Recent technological advances in whole tree utilization (Young 1968) and pulping of tree parts such as branches, tree tops, and stumps (Chase *et al.* 1971, 1973) are likely to drastically change methods of harvesting and merchandizing pulp species. Weight rather than volume will be used in commercial transactions in the near future and weight tables will have to be prepared for many species used for pulping. The existing information on standing biomass and biomass production of stands is inadequate both from the standpoint of number of species for which the information is available and their geographical location. Little basic biomass data are available for genetically improved forest tree species.

In intensive culture, rapidly growing species would be mechanically planted on suitable land after adequate site preparation, would be fertilized and irrigated, and mechanically harvested when the mean annual biomass growth of the plantation culminates. The most favorable rotation age will have to be determined for various species and hybrids grown at various spacings under a variety of treatments including cultivation, fertilization, and irrigation. The studies proposed here are designed to provide such information for northern Wisconsin.

APPROACHES AND MODELS USED IN BIOMASS STUDIES

Methodology for assessing standing biomass and biomasss production of stands by both destructive and nondestructive sampling has been investigated by forest ecologists since the 1950's (Ovington 1956, 1957; Ovington and Pearsall 1956). A brief review of three frequently used methods follows.

One of the earliest and most expedient methods was the mean tree method in which one or more trees of mean dimensions was harvested and total biomass per unit area obtained by simple expansion based on density. The main assumption of this method is that a tree of mean dimensions is also a tree of mean biomass. This assumption is approximated in even-aged plantations of intolerant species such as pines (Ovington 1956, 1957; Ovington and Pearsall 1956), but biomass estimates of stands of tolerant species and natural stands obtained by this method may be in error by as much as 50 percent (Baskerville 1965b, Crow 1971).

The second method, called unit area, was used by Bray and Dudkiewicz (1963) in biomass studies of *Populus* forests. Projected crown area and total biomass of each sample tree were determined and biomass expressed per unit land area. This approach was found to be the least reliable in a comparative study of three approaches used for biomass estimation (Ovington *et al.* 1967). A modification of this method was used by Zavitkovski and Newton (1968) in biomass studies of *Ceanothus velutinus*, a nitrogen-fixing shrub of the Oregon Cascades. All shrubs were harvested from sample areas of 40.5 square meters (1/100 acre) and fresh weight obtained in the field. A representative subsample was taken for fresh weight/dry weight ratio determinations. This method has also been used by various workers for biomass determination of young tree plantations (Person *et al.* 1971, Heilman *et al.* 1972, Saucier *et al.* 1972, Crist and Dawson 1975).

The most reliable method for biomass estimation is regression analysis, also called dimensional analysis by Whittaker and Woodwell (1968), or allometry by Kira and Shidei (1967). In this method, the dependent variable, i.e., whole tree or tree component dry weight, is expressed as a power function of some easily measurable independent variable, mostly Dbh, Dbh^2, height, or a combination thereof. For statistical purposes and curve fitting, the original form of the allometric equation $Y = aX^b$ is transformed to a logarithmic form: $\ln Y = \ln a + b \ln X$. This transformed form has a statistical advantage because it normalizes the variance of biological data that often follow a lognormal distribution (Baskerville 1972).

Problems arise when the log-transformed units are transformed back to the original arithmetic units, because if lnY is normally distributed, Y distribution is skewed. This problem was recognized first by mathematicians (Finney 1941) and later by ecologists when the use of allometric equation became common in ecology (Madgwick 1970). Correction procedures for the bias have been proposed by Baskerville (1972).

Goodness of fit of the data in regression techniques can be evaluated in various ways. The coefficient of determination, R^2, is used by most workers. A different measure, essentially equivalent to a coefficient of variation, called $\underline{e}$ or $\underline{E}$, is advocated by Whittaker and Woodwell (1968). For regressions in arithmetic units, $\underline{e}$, or estimate of relative error, is obtained by dividing the standard error, $S_{y.x}$, by the mean value of the dependent variable Y. In the allometric regressions, the standard error of estimate is a logarithm added to or substracted from an estimate of lnY; its antilog is a factor by which a given value of Y is multiplied or divided. A value of $\underline{E}$, the estimate of relative error for a logarithmic regression, equal 1.25 thus suggests an expected error range from 1.25Y to Y/1.25.

APPLYING ALLOMETRY IN BIOMASS STUDIES

The first step in estimating biomass production of forest stands is to develop equations relating some easily measurable variables, usually dbh and height, with dry weights of whole trees and tree components (Zavitkovski 1971). Sample trees are selected in target stands avoiding the border trees which are atypical. Sample allocation should be based on dbh or tree basal area distribution so that the whole range of sizes is represented. Sample size (i.e., number of sample trees) will depend on the variability, allowable sampling error, and manpower available. For components whose variability is high, such as dead branches and foliage, a prohibitively large sample would have to be collected to obtain a low sampling error so, a compromise will have to be made in which the sample size will be determined by the most important component, usually the biomass of stems.

Sample trees are cut at the ground line and separated into components of interest (e.g., stem, branches, leaves, etc.), bagged and dried at 70°C to equilibrium. For large trees, fresh weights of individual components are obtained in the field and subsamples of each taken for dry/weight fresh weight ratio determination. Dry weights of individual components are obtained by multiplying fresh weights by the ratio. Allocation of subsamples should be at random and subsample size proportional to weight variation of the component. As a rule, stem sections of the same length, regularly spaced along the stem, are taken for stem wood and stem bark weight determination. One or more branches are taken at random from each whorl or annual height growth increment and all leaves from the sample branches separated and bagged. Fresh weights of each subsample are obtained in the field and dry

weights after drying in the laboratory. Desirable precision of weighing, which is assumed to be without error, is to 0.1 percent of the weight, i.e., for weights of 100 grams to the nearest 0.1 gram.

Modifications of the general method may be required for some specific sampling. Leaves (needles) of evergreen species may be separated into current year's and older classes. Estimates of leaf biomass of deciduous stands may be obtained from litter sampling which, for less effort, yields more accurate data.

Plotting of the data may indicate which independent variables should be used in fitting the allometric model by the method of least squares. Corrected values are calculated as discussed by Baskerville (1972):

$$Y = \exp(\ln Y' + \sigma^2/2)$$

where Y and Y' are the estimated corrected and uncorrected values in arithmetic units, (Y' from the allometric regression), and σ^2 is sample variance of the logarithmic equation. The variance, σ_A^2, for the skewed distribution of Y's in arrthmetic units, is calculated as follows:

$$\sigma_A^2 = \exp(2\sigma^2 + 2 \ln Y') - \exp(\sigma^2 + 2\ln Y').$$

ESTIMATING STAND BIOMASS

Stand biomass is estimated by the method of "every-tree summation" (Baskerville 1965b). Dbh, height, or other variables used in the allometric regression are measured on all trees (excluding border trees) of a plantation and biomasses of all trees, corrected for bias resulting from log-transformation, summed. The standing biomass is then expressed in metric tons per hectare or other units relating weight and area. For large plantations, sample area approach, such as used in forest inventory (Freese 1962), may be used.

Time of biomass estimation is important especially if two successive estimates are used for estimating biomass production. The measurements should be taken during the dormant season avoiding, however, very cold days on which dbh measurements, and consequently biomasses of trees, would be underestimated (Godman and Mattson 1970).

ESTIMATING BIOMASS PRODUCTION

Newbould (1967) presents two basic models for estimating biomass production (P) of a single tree or whole forest stand:

$$P = \Delta B + L + G \quad (1)$$

$$P = B_c + L + G \quad (2)$$

In the first approach, biomass (B) is measured twice at times t_1 and t_2 and the difference (ΔB) is the biomass change during that time (Model 1). In the second approach, instead of measuring the biomass twice, trees are harvested at the end of the growing season and by means of stem analysis and separating the current year's organs (e.g., twigs) for the current growth, B_c is estimated (Model 2). In both Models, the losses by death and shedding (L) and by organisms (G) must be added.

A third approach, applicable to uneven-aged forest stands was used by Zavitkovski and Stevens (1972) in studies on biomass growth of red alder stands in Oregon. Standing biomass of 50 red alder stands containing trees ranging in age from 1 to 65 years and growing on latosolic soil of similar productivity was determined during the leafless period in winter. Relations between an index of volume (dbh^2 x height) and dry weight of individual tree components and whole trees were established by analyzing 119 felled sample trees and biomasses of stands obtained by the method of every tree summation discussed previously (Baskerville 1965b). Von Bertalanffy's growth model was fitted to the above ground dry weight of stands as a function of age by a method described by Ricklefs (1967). Mathematically, the first derivative of this function is equivalent to ΔB of Newbould's (1967) equation 1 shown above, i.e., stand biomass change from t_n to t_{n+1}. Total annual biomass production, P, is then obtained by adding losses, i.e., mortality, litter fall, and consumption by organisms, to ΔB.

ROLE OF CANOPIES IN BIOMASS PRODUCTION

Positive and significant relations were found between leaf area index, LAI, and production of various crop plants (Donald 1961, Williams 1966), but the information on the role of LAI in biomass production of forests is inadequate (Zavitkovski *et al.* 1974). In broadleaved deciduous forests, LAI's ranged

from 3.1 to 14.2 (Tadaki and Shidei 1960, Chalupa 1961, Whittaker and Woodwell 1968, Assmann 1970, Art and Marks 1971) and from 6 to 13 (or 12 to 26 for both sides) in coniferous and other evergreen forests (Tadaki *et al.* 1965, Kira *et al.* 1969, Assmann 1970).

The information on leaf biomass, which is used by production ecologists in a way similar to the way plant physiologists use LAI, is more comprehensive. In deciduous forests, leaf biomasses were estimated indirectly from litter traps (Bray and Gorham 1964, Zavitkovski and Newton 1971), while in coniferous stands direct determinations were usually made (Baskerville 1965a, Fujimori 1971). Leaf biomass of the deciduous forests ranged from about 2 to 6.6 metric tons per hectare whereas coniferous forests had as much as 22 metric tons per hectare primarily because of the longevity of needles in some species.

In a recent review of forest biomass studies, Zavitkovski *et al.* (1974) found a positive relation between the leaf biomass and net annual production of stems and branches for stands of numerous tree species. In general, foliage of the deciduous species was found to be more efficient than that of evergreens in producing stem-branch biomass. On the average, 1 metric ton of foliage produced 1 metric ton of stems-branches in the coniferous and 2.17 metric tons in the deciduous forests. The variability of the data prevented any detailed analysis on the possible reduction of stem-branches production in stands having very high leaf biomasses. However, a detailed study of red alder (Zavitkovski and Stevens 1972) indicated that productivity was reduced when the leaf biomass was higher than 5.6 metric tons per hectare. Stated differently, an optimum leaf biomass for natural red alder stands was about 5.5 metric tons per hectare (Zavitkovski *et al.* 1974).

From the production standpoint, the concept of optimum leaf biomass or LAI is very important for maximizing biomass production. Experimental plantations seem to be suited for such studies because their densities can be better controlled than in natural stands.

ENERGY CONVERSION IN INTENSIVELY MANAGED STANDS

Closely related to leaf biomass and dry matter production is the efficiency of solar energy (light) utilization of a stand. Hellmers and Bonner (1959) suggested that forest communities utilize only 2 to 2½ percent of the visible portion of the incoming solar energy. By contrast, the best managed field crops may utilize 2 to 5 percent and algal cultures 7 to 10 percent (Wassink 1959, Talling 1961, Bonner 1962). Forest biomass studies conducted since the 1960's show that both planted and natural forest communities are more efficient than suggested by Hellmers and Bonner (1959). Natural stands of red alder may utilize up to 4.4 percent of the growing season's light and natural stands of western hemlock about 2.8 percent of a whole year's light. In intensively cultured stands, even greater light utilization may be reached.

Solar energy incorporated into an intensively managed stand is a product of dry matter production and energy content per unit weight obtained by calorimetry. Results are expressed in kilocalories per hectare per year. Efficiency of solar energy conversion is determined from the total energy incorporated into annual biomass production and incoming solar radiation measured by a solarimeter. Results are expressed in percent of growing season's or whole year's solar energy input over the total or visible spectrum (400 to 700 nm).

OPTIMUM ROTATION AGE

With no economic constraints imposed, the optimum rotation age would be reached when the mean annual biomass growth culminates. This occurs several years after the culmination of the net annual growth. For example, in red alder, the optimum rotation age was achieved at 21 years but the peak was flat indicating that between 16 and 27 years production would be within 5 percent of maximum (Zavitkovski *et al.* 1974). From the utilization standpoint, proportion of dead tree biomass may be important for fiber production because in whole-tree harvesting, standing dead trees would be harvested along with the living trees. However, the data for red alder stands indicate that between ages 12 and 35 years standing dead trees account for less than 5 percent of the total biomass.

Economic constraints, especially at current high interest rates, would reduce the optimum biological rotation. For aspen stands in the Lake States, Einspahr and Benson

(1968) considered an economic rotation between 10 and 20 years possible, and Ek and Brodie (1975) from 20 to 30 years. Ek and Brodie suggested that extremely short rotations (less than 15 years) would be undesirable because volume and value growth rates are sustained into the third decade. For intensively culuted *Populus* 'Tristis #1', grown for 5 years at six spacings ranging from 0.75 to 12 feet, Ek and Dawson (in press) projected optimum biological rotations from 8 to 15 years, indicating that optimum economic rotations would be less than 10 years. Such short rotations have also been projected for intensively cultured sycamore in southern United States (Steinbeck *et al.* 1972).

PRELIMINARY STUDIES ON POPULUS TRISTIS CANOPIES

Studies on leaf biomass production were begun in 3-year-old experimental plantations of *Populus tristis* established at four spacings--1 by 1, 2 by 2, 4 by 4, and 8 by 8 feet--from rooted tip cuttings in 1972. The plantations were small, ranging in size from 16 by 36 feet for the 1 by 1 foot spacing to 48 by 144 feet for the 4 by 4 and 8 by 8 foot spacings. Small plots can produce biased results, so larger plots will be needed for final confirmation of the data.

Leaf biomass of canopies was estimated by two methods: (a) litter sampling and (b) destructive sampling. Indirectly, the equilibration of leaf biomass in the sampled stands was estimated by measuring light under canopies.

In late summer of 1975, six 0.5 by 0.5 meter litter traps were placed in each of the four plantations and litter sampled at biweekly intervals until mid-September; subsequent litter sampling was done at weekly intervals. Leaves were separated from other litter components, dried at 70°C, and weighed. Results from the six traps were averaged and expanded to hectare basis (table 1). The data indicate that the leaf biomass of the 1 by 1 and 2 by 2 foot plantations reached, or approached, the equilibration quantity, i.e., the biologically attainable quantity for the type of the plantations studied under the existing environmental conditions. The ratio between the specific leaf weight of leaves in the litter and those collected (green) from standing trees was 1.57, i.e., leaf biomass estimated from litter trapping must be multiplied by 1.57 to obtain an estimate of leaf biomass of living canopies. For example, for the 1 by 1 foot plantation, in which litter sampling reached 3.3 metric tons per hectare, the corresponding dry weight of green leaves is about 5.18 metric tons per hectare (standard deviation 0.63 metric tons per hectare). These values are likely to be underestimates of true leaf biomasses because in small plantations some leaves may be lost due to wind.

Leaf biomass of the stands was also estiimated from destructive sampling. Three trees were destructively sampled in the 1 by 1, 2 by 2, and 4 by 4 foot plantations. Diameters of all branches were measured 2.5 centimeters from the stem and leaves from a 10-percent sample of branches separated, dried, and weighed. Dry weights of leaves (dependent variable) were related to branch diameters (independent variable) and the regression used in estimating total leaf biomass of individual sample trees. Finally, total leaf biomass of sample trees (dependent variable) was related to tree dbh

Table 1.--*Leaf litter, leaf biomass, and light regime in 3-year-old plantations of* Populus Tristis

Spacing (feet)	Leaf litter per hectare: Mean	Leaf litter per hectare: Range	Canopy leaf biomass per hectare: Mean	Canopy leaf biomass per hectare: $S_{y.x}$	Light intensity: Mean	Light intensity: Range	Light in the open
	Metric tons	Metric tons	Metric tons	Metric tons	Foot-candles		Percent
1 by 1	3.30	2.69-3.90	6.24	0.68	37	19-58	0.53
2 by 2	3.23	2.74-3.76	5.41	1.07	39	14-83	.57
4 by 4	2.60	1.30-3.17	3.61	.30	66	45-310	1.87
8 by 8	1.58	1.21-1.83	n.a.		3215	70-7,200	45.5

(independent variable) and used to calculate leaf biomass of total plantations (excluding border trees). Results were similar to those obtained from litter sampling after the quantities of leaf litter were adjusted by the ratio of 1.57 (table 1).

Light was measured about 30 centimeters above ground with a photometer around noon on a clear day on July 30, 1975. The readings were taken under canopies at points systematically located along three transects in each plantation. Light in the open was measured between measurements along each successive transect. Average light intensities under the 1 by 1 and 2 by 2 foot plantations were only 0.53 and 0.57 percent of the light in the open, and the absolute light intensities were 37 and 39 foot-candles, respectively (table 1).

Results indicate that the canopy leaf biomass of about 6 metric tons per hectare (or 3.5 metric tons per hectare of leaf litter) may be the upper limit that can be attained under field conditions. In the same experimental area, leaf biomasses ranging from about 2 to 4.8 metric tons per hectare were determined by Ek and Dawson (in press) in other 3- and 4-year-old plantations of *Populus tristis*. Although not strictly comparable to *Populus* canopies, canopy biomasses of natural red alder stands in Oregon averaged about 5.5 metric tons per hectare and remained stable between ages 4 and 30 years (Zavitkovski and Newton 1971). It seems unlikely that the leaf biomass of *Populus tristis* can increase much beyond 6 metric tons per hectare because even on sunny days photosynthesis of the lowermost leaves probably does not reach a compensation point. On cloudy days the situation becomes even more critical.

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COOPERATIVE AND RELATED FOREST RESEARCH AT THE INSTITUTE OF PAPER CHEMISTRY

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Investigations underway that relate to the maximum yield research program include: (1) The Mass Production of Conifer Tree Hybrids--a program using tissue culture and protoplast fusion techniques to produce large numbers of useful hybrids, (2) Bark Characteristics of Important Pulpwood Species--a study of the fundamental bark characteristics important to segregating, pulping, and/or use of bark as fuel, and (3) The Production and Intensive Management of Genetically Improved Aspen--a program aimed at obtaining maximum per acre cellulose yield and improved fiber quality.

The Institute of Paper Chemistry has three projects that relate in various ways to the maximum yield research being undertaken by the USDA Forest Service. The objectives, methods, and progress of each project are briefly reviewed here.

PROJECT 3223 "THE MASS PRODUCTION OF CONIFER TREE HYBRIDS"

The primary objective of this research program is to find ways to mass produce conifer tree hybrids using tissue culture and protoplast fusion techniques. Another extremely important objective is to develop a procedure that will make it possible to start with single cells in suspension and go to embryoids and then to plantlets and finally to trees. The potential of hybridization in conifers has not been developed sufficiently to meet our future wood raw material requirements. The difficulty of producing large numbers of conifer tree hybrids was determined as one of the principal reasons conifer hybrids have not been widely grown in the past. The goal of this research program is to inexpensively mass-produce conifer tree hybrids and/or genetically superior selections using tissue culture techniques.

The program employs the scientific know-how from the field of biochemistry, electron microscopy, and plant physiology. Early emphasis has been on the differentiation of shoots on stem and cotyledon callus and the production of embryoids in cell suspensions. The work on protoplast fusion is being delayed until adequate progress has been made in the cell suspension work. Biochemical and morphological comparisons between several sources of callus and young organized tissue are underway. The two species under investigation are Douglas-fir and loblolly pine.

Early progress has been good, with Douglas-fir shoots being produced from a special source of callus from 11 different Douglas-fir clones (fig. 1). Embryoidlike structures have been developed in both Douglas-fir and loblolly pine cell suspensions and work is underway to trigger these structures to continue to develop into true embryos and eventually into plantlets (fig. 2). The program, despite its highly technical nature, has a very practical objective and the procedure is envisioned as starting in the laboratory

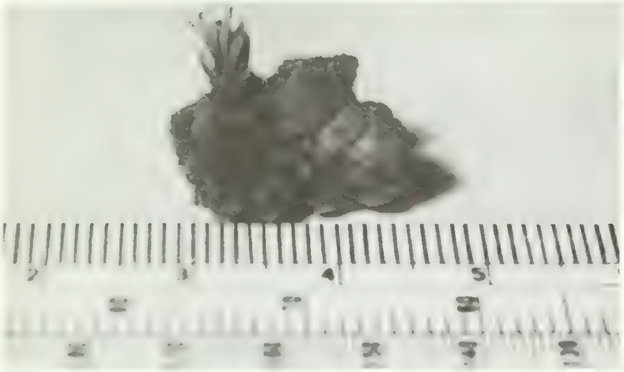

Figure 1.--*One of the first shoots produced on Douglas-fir cotyledon callus. Magnification--6X.*

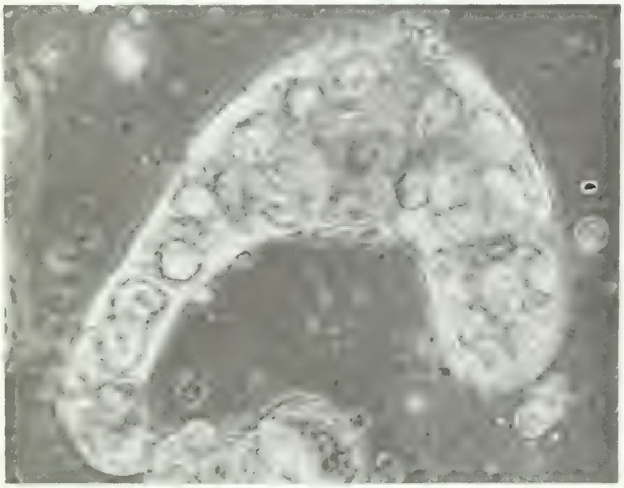

Figure 2.--*Embryoidlike structures developed in Douglas-fir cell suspensions. Magnification--430X.*

and ending with the production of container-grown plantlets produced in the greenhouse.

PROJECT 3212 "BARK CHARACTERISTICS OF IMPORTANT PULPWOOD SPECIES"

The objective of this project is to provide information on the fundamental properties of bark (and wood) for 32 pulpwood species. The information is expected to help member companies determine the usefulness of a particular tree species as a raw material and assist in determining how the species might be harvested and handled to adequately segregate wood from bark. Emphasis is also being given to providing the information required to determine the consequences of pulping bark and use of bark as fuel.

Some standard tests have been set up to characterize the bark for each tree species. Included in the characterization for each species is the following information: silvicultural characteristics and geographic range, wood and bark morphology, wood and bark specific gravity and extractives, bark fibrous yield, wood/bark adhesion, bark strength and toughness, water flotation behavior, total ash and calcium, and fuel value of the bark.

The bark characteristics of 20 species have been investigated to date. Major differences in dormant season wood/bark adhesion, ash and calcium content of the bark, fibrous material in the bark, and strength of the bark have been discovered (table 1). Most conifer bark contains no fiberlike elements while most hardwood barks investigated contain a modest amount of fiber (fig. 3).

Screening and mechanical treatments that capitalize on the differences in strength between wood and bark seem to offer the most promise as ways of reducing bark levels in wood chip/bark mixtures. For hardwoods, a good correlation seems to exist between bark specific gravity and bark removal (high specific gravity gives best removal). This does not seem to be true for the conifers investigated. For conifers, bark thickness particularly the outer bark, seems to be a factor. Removing bark by hammermilling has been less effective for conifers than hardwoods (tabl 2). In this test, pure fractions of either wood or bark are fed into the hammermilling apparatus, caught in a cloth bag, and screened.

The information illustrated and the other basic tests are designed to identify the pulp and paper industry's bark problem and make it possible to take advantage of whole-tree chipping techniques and the promising short-rotation forest management systems being developed.

PROJECT 3250 "PRODUCTION AND INTENSIVE MANAGEMENT OF GENETICALLY IMPROVED ASPEN"

This project is a streamlined version of two larger research projects. The

Table 1.--*Bark pulp yield and usable fiber*
(In percent)

Hardwoods	Bark pulp yield	Usable bark fiber[1]	Conifers	Bark pulp yield	Usable bark fiber[1]
Quaking aspen	34	10	White spruce	21	0
Eastern cottonwood	35	9	Balsam fir	26	0
Sweetgum	35	5	Jack pine	19	0
Sugar maple	34	3	Loblolly pine	24	0
White birch	36	0	Slash pine	24	0
Northern red oak	28	5	Douglas-fir	18	5
Southern red oak	31	4	Western hemlock	36	0
Northern white oak	35	3	Lodgepole pine	27	0
Southern white oak	37	3	Ponderosa pine	29	0
			Engelmann spruce	24	0
			Western larch	28	1

1/ Usable bark fiber is the fiber retained on 60- and 100-mesh screens. The percentage given is the yield based on whole bark samples.

Figure 3.--*Aspen bark fiber retained on a 60-mesh screen. Magnification--75X.*

program combines the aspen genetics research that has been underway since 1955 with an aspen intensive management program started in 1968. The objective of the new program is to bring together the knowledge acquired over the past 20 years and formulate a forest management plan for aspen hybrids that will obtain the maximum per acre fiber production and improve fiber quality.

The genetics phase of the program employs selection, hybridization, and polyploidy in an effort to produce trees that grow faster and have better wood properties than native aspens. The intensive management phase of the project has investigated the possibilities of

Table 2.--*Hammermilling results*[1]
(In percent)

Hardwoods	Bark removed	Wood loss	Conifers	Bark removed	Wood loss
Quaking aspen	34	5	White spruce	23	4
Eastern cottonwood	18	5	Balsam fir	44	6
Sweetgum	32	7	Jack pine	26	5
Sugar maple	29	5	Loblolly pine	34	6
White birch	38	6	Slash pine	36	5
Northern red oak	34	10	Douglas-fir	28	4
Southern red oak	46	6	Western hemlock	24	3
Northern white oak	37	5	Lodgepole pine	31	4
Southern white oak	38	3	Ponderosa pine	26	4
			Engelmann spruce	25	4
			Western larch	26	6

1/ Based upon simulated hammermilling, followed by screening, using the on 14-mesh screen to remove bark and recover usable fiber from fines.

converting low-quality northern hardwood stands to hybrid aspen. It includes test plantings of aspen hybrids and native sucker stands that have been fertilized and irrigated to determine the biological potential of such procedures and the impact of rapid growth on wood quality.

We have produced a number of aspen hybrids that grow twice as fast as native aspen and have superior fiber properties (fig. 4, table 3). Arboretums are being established with several of the cooperating companies to facilitate the mass production of the better hybrids. Growth response from fertilization and irrigation has been similar to that for other tree species. Specific gravity was decreased 6 to 8 percent and fiber length increased 4 to 6 percent by treatments that increased volume growth about 100 percent. The aspen hybrids have responded better to fertilization than the native aspen trees. A recently completed economic analysis indicates that a rate of return of 6 to 6-1/2 percent can be expected from growing aspen hybrids compared to much less wood production and a rate of return of 5 to 5-1/2 percent from growing red pine in northern Wisconsin.

Figure 4.--*Three-year-old triploid hybrid clone growing in northern Wisconsin.*

Table 3.--*Wood and kraft pulping properties of triploid hybrid aspen*

Type of material	Wood specific gravity	Pulp fiber length	Screened pulp yield	Handsheet properties[1/]		
				Tear	Burst	Tensile
		mm	*Percent*			
Mature native aspen	0.349	0.91	52.6	75.7	51.5	10.3
15-Year-old native aspen	.350	.79	52.1	73.0	48.0	9.9
10-Year-old triploid hybrid aspen	.420	.94	53.5	88.0	55.7	10.1
15-Year-old triploid hybrid aspen	.401	1.00	51.2	96.0	58.0	10.4

1/ Measurement at 750-ml Schopper-Riegler freeness; tear and burst are TAPPI factors; tensile is breaking length in km.

DETERMINING MOISTURE-NUTRIENT REQUIREMENTS FOR MAXIMUM FIBER YIELD

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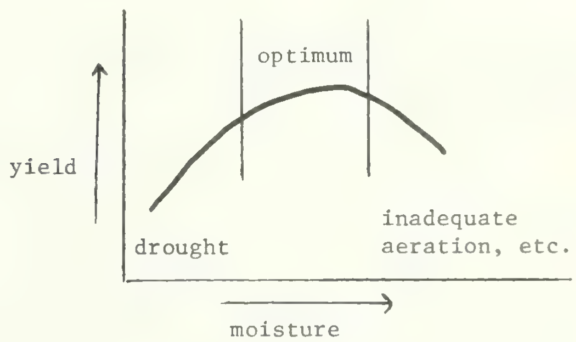
Nutrient-moisture requirements for maximum fiber yields will be determined in a series of growth room, greenhouse, and field studies. Irrigation and fertilization indices will also be developed for use in management systems.

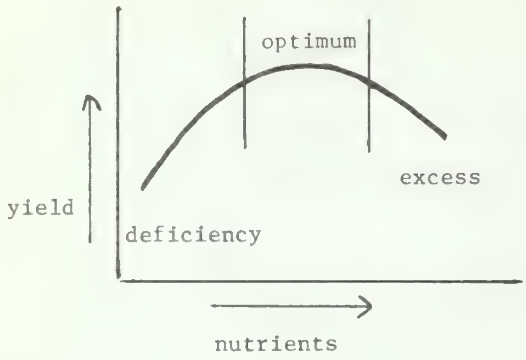
There have been no project studies on the nutrient-moisture aspects of maximum yield forestry specifically, although some cooperative growth room-greenhouse studies were conducted at Iowa State University (Dykstra 1974, Domingo and Gordon 1974). Irrigation and fertilization of current field test plots is based on the best available information on tree nutrition combined with good farming practices. However, we wish to move beyond just creating and maintaining *good* growing conditions; we want to establish as precisely as possible nutrient and moisture levels necessary for *maximum* yield. In addition, we want to examine the influence of various levels of input on yield, determine the effects of maximum-yield management on wood quality, and develop the capability for matching species and clones to nonirrigated but intensively managed sites. To accomplish this, we will look at the effects of nutrient-moisture variables on the growth of many species and clones in a series of growth room, greenhouse, and field studies carried out over many years.

The general relations between nutrient and moisture effects on plant growth are well established. Plant growth usually increases with increasing moisture supply up to some optimum level:



Eventually a moisture level is reached (with the exception of "swamp species") at which other factors become limiting to growth. Inadequate soil aeration is one such factor sometimes encountered (Domingo and Gordon 1974). One project objective is to define the optimum water levels for several different tree species and clones.

Plants respond to fertilization in much the same way they do to water (Morrison 1974):



There is an area of deficiency, an optimum range, and an area of excess. Another project objective is to define the optimum nutrient levels for the same tree species and clones.

Determining optimum nutrient-moisture conditions is complicated by the fact that they are interdependent. Generally, plant growth increases with increasing moisture and nutrient levels (fig. 1). However, because of this water-nutrient-growth interaction, nutrient requirements may be decreased at low moisture levels as depicted by the hatched band. In fact, heavy fertilization can retard growth on dry sites because excessive nutrients in the soil can increase salt content creating plant water stress (Dickson 1971, Black 1965). This can also happen under fairly high soil moisture conditions. On the other hand, excessive soil moisture can sometimes cause inadequate soil aeration thereby reducing growth.

We want to define the combinations of fertilizer and water necessary for optimum growth as depicted by the circled area in figure 1. A few published studies on foliar nutrient levels required for maximum growth showed little difference among the *Populus* species tested (table 1). However, we still need to see if this holds true for our particular hybrids because

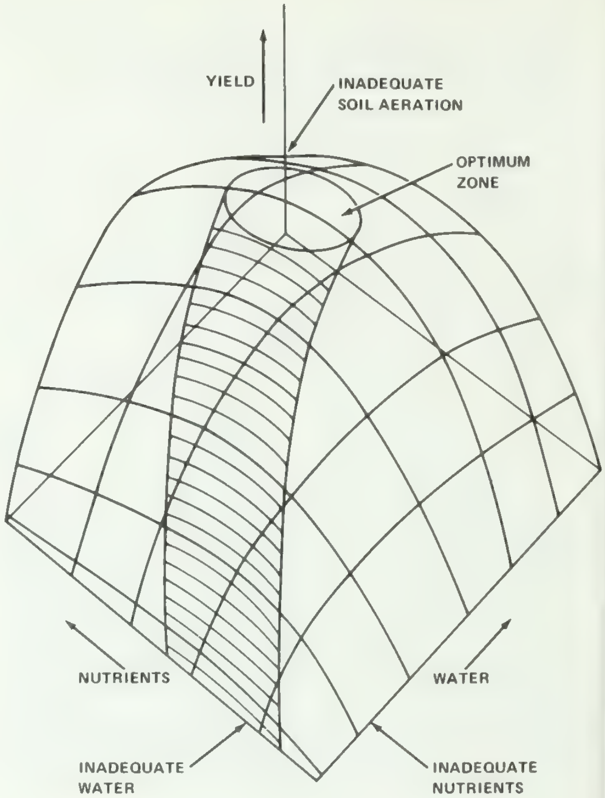


Figure 1.--*Effect of nutrient-moisture interactions on tree yields.*

nutrient-water requirements for maximum growth may vary from clone to clone. This potential for different requirements will be checked in a series of studies with our cooperators. To gather this information will require growth-room studies of interclonal variation and (if differences exist) field tests to check results over a rotation period. Eventually we will have the information necessary to grow each clone under its optimum conditions. Optimum growing conditions are necessary in order to make valid comparisons in clonal screening tests and in yield studies in large plantations.

Table 1.--*Foliar concentration for maximum growth*
(In percent by dry weight)

Species	Nitrogen	Phosphorous	Potassium	Calcium	Magnesium	References
E. cottonwood *(Populus deltoides)*	3.5-4.5	0.5-0.7	3.0-4.0			Bonner and Broadfoot 1967
Quaking x E. gray pop. *(Populus canescens x P. tremuloides)*	4.3-4.4	.51-.60	2.8-3.3	0.56-0.63	0.35-0.45	Einspahr 1968
Bigtooth x E. gray pop. *(Populus grandidentata x P. canescens)*	4.0-4.3	.58-.65	2.8-3.0	.40-.62	.23-.40	Einspahr 1969

Although it is essential to determine the nutrient-moisture requirements for maximum growth, much additional information is required before maximum yield forestry can be adapted into a management system. Some of the necessary areas of research are as follows:

1. Determine the water consumed in dense irrigated plantations to aid in designing irrigation system capacity.

2. Determine the optimum amount and timing of irrigation and develop an irrigation index. Soil water monitoring to determine when to irrigate is complicated by the fact that the rapidly elongating root system of young trees penetrates to ever greater depths, thus continually changing any relation between soil water availability as indicated by a sensor and that available to the plant roots. Therefore, an index based on plant water potential rather than soil water will probably provide better irrigation control.

3. Investigate the extent of inter-tree transfer of nutrients and water through root grafts and/or closely associated roots. If such inter-tree transfers occur, we would need larger test plots and buffer strips to isolate one treatment from another. However, irrigation and fertilization could then be less uniform in a managed plantation because inter-tree transfers would tend to lessen any differences in application.

4. Monitor the uptake of nutrients by the plant so as to maintain nutrition at optimum levels. A tissue test should be developed so that nutrient status can be determined early in the growing season and fertilizer applied in the amounts and at the time it does the most good.

5. Determine the growth potential of selected *Populus* clones and other species when grown without irrigation but with otherwise optimum conditions. Then drought resistant clones can be selected for nonirrigated sites where the trees must depend on the available water in the soil profile.

6. Monitor the effect of intensive forest practices on groundwater contamination and soil changes. Although such effects will probably not be any greater than those from standard agricultural practices, any such changes should be documented. If severe, ways should be determined to reduce their impact by modifying cultural practices.

Because of the nature of the project mission, some added criteria influence research strategy. First, we are concerned with *maximum* yields so we would like to be as precise as possible in our recommendations for irrigation and fertilization. Second, because of the long rotations involved (compared with agricultural crops), undesirable clones must be rapidly screened out in order not to waste time and money in full-scale field tests (see paper by Paul Wray in this Proceedings). These two factors dictate that we use "quick" growth-room or greenhouse tests in many instances before moving into long-term field studies. This approach requires measurement techniques that can be applied regardless where or how a study is done so as to provide a common data base for extrapolating results from study to study. Consequently, water potential and nutrient measurements will be concentrated on the plant itself rather than on the much more variable soil-plant environment. This will involve plant water potential measurements with a pressure bomb and/ or thermocouple psychrometer, and plant tissue analysis for nutrient status.

However, soil moisture and nutrient data will still be collected in field studies. Whereas plant water potential measurements determine *when* to irrigate, soil moisture measurements are necessary to determine *how much* water to add to bring soil moisture back to field capacity. Likewise, soil nutrient data will complement the tissue data and together may eventually provide a firmer basis for fertilization recommendations.

In summary, the research strategy is to initiate a series of growth-room, greenhouse, and field studies (some project studies, some cooperative) emphasizing plant measurements for nutrients and water. The objectives are to define optimum growing conditions for various clones and species, develop the capability for matching species to nonirrigated sites, and to develop the necessary cultural techniques and indices for full-scale management for maximum yields.

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SOME PROBLEMS OF ESTABLISHING AND MANAGING INTENSIVELY CULTURED PLANTED STANDS

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The need for intensive site preparation and competition control for converting hard-to-plant sites to fast growing stands of economically desirable species is discussed. Jack pine, red pine, white spruce, and hybrid Japanese-European larch seedlings raised in 3-M polymer blocks and Spencer-Lemaire Rootrainers grew larger and survived outplanting better than stock grown in two sizes of Polyloam blocks. Average survival for all species for these two best containers was 68 percent. Intensive site preparation followed by factorial combinations of Casoron and Roundup herbicide to control weeds resulted in lower survival where Casoron was applied.

A key step in establishing and managing intensive culture plantations is removing the existing vegetation and establishing in its place improved plant material better adapted to the site. The fact that most sites needing reforestation support stands of trees or shrubs makes the task totally different than it was 40 or 50 years ago. Effective methods must be found, therefore, to prepare sites before planting and suppress subsequent weed growth at least until the new plantation has occupied the site and weed competition is no longer a deterrent to survival and growth.

Equally important to successful plantation establishment is the vigor and physiological state of the tree seedlings to be planted. If the trees are in poor condition at the time of planting, due to desiccation or root damage, for example, successful competition with weeds becomes even more difficult.

To deal with these problems, we are studying two approaches that together may enhance the trees' early competitive ability: (1) the effect on tree growth and survival of mechanically and chemically removing or suppressing competing vegetation, and (2) the use of container-grown seedlings for planting stock.

Containerized seedlings are grown in individual containers in the greenhouse to plantable size. After a period of hardening outdoors, the trees are outplanted with or without the containers, depending on the containers used. The big advantage of containerization is that the seedling root system is protected against disturbance and drying (fig. 1).

Figure 1.--*The Spencer-Lemaire "Rootrainer."*

In April 1974 we began a preliminary study to evaluate several elements of plantation establishment and management: (1) species, (2) container systems, (3) herbicidal effects on the trees and competition, and (4) site preparation.

GREENHOUSE TEST

Seeds of white spruce (*Picea glauca* (Moench) Voss), red pine (*Pinus resinosa* Ait.), jack pine (*Pinus banksiana* Lamb.) and a hybrid larch (*Larix decidua* x *L. leptolepis*) were sown in the following containers: (1) The Spencer LeMaire "Rootrainer,"[1/] a folding type of plastic container with cavities each holding 10 cubic inches (164 cubic centimeters) of a 3:1 peat moss and vermiculite mix; (2) rectangular Polyloam blocks (polyurethane foam) of two sizes--2¼ and 5 cubic inches (37 and 82 cubic centimeters); and (3) rectangular blocks 5 cubic inches (82 cubic centimeters) in size formed by bonding a 3:1 peat moss and vermiculite mix with a hygroscopic polymer (3-M Co.). Fertilizer was applied about every 2 weeks to the 3-M polymer blocks and Rootrainer seedlings. The Polyloam reportedly contained sufficient slow-release fertilizer to maintain plants for about 5 months. Artificial light was given to extend the photoperiod to 20 hours per day.

During the early stages of the study, two problems were encountered that appeared to be related to the properties of the different containers. In the Polyloam containers, germination of white spruce and jack pine seed was noticeably slower than in the other containers and in many blocks germination failed to occur. This was probably due to the difficulty in maintaining a proper moisture content in the Polyloam blocks.

Root rot caused some mortality in the Rootrainers. Better aeration properties of the other blocks probably prevented a buildup of the disease in these containers. In late July, after 4 months, the seedlings were removed to a lath house and allowed to harden under outdoor conditions for about 4 weeks before planting. At this time, significant differences in the growth of all species due to container type showed up: generally, the Rootrainer and 3-M polymer containers produced taller seedlings than the Polyloam (table 1).

Table 1.--*Average shoot lengths of four conifer species grown in four containers* (In centimeters)

Container [1/]	Jack pine	Red Pine	White spruce	Larch
Large Polyloam block	9.3	5.9	3.2	11.8
Small Polyloam block	9.3	6.1	2.2	9.9
Rootrainer	12.8	10.1	7.3	11.8
3-M Polymer block	13.6	10.8	6.4	20.3

1/ There are statistically significant differences between container systems, but analysis to identify differences between individual systems has not been run at this preliminary stage of the study.

OUTPLANTING TEST

The planting site is part of the Three Lakes Ranger District, Nicolet National Forest, Wisconsin. The vegetation on the site was mostly sod with some scattered aspen, indicating a history of severe fire. Soils are a sandy loam of the Padus Series.

The site was prepared in cooperation with National Forest personnel. A crawler tractor with straight blade leveled and cleaned the site so it could be disced with a farm tractor (fig. 2). The leveling operation removed much of the top layer of soil. Rocks exposed by the crawler tractor interfered with discing.

A completely randomized block design was used for outplanting. Seedlings were spaced at 6 feet in square 16-tree plots.

Figure 2.--*A light farm tractor with disc removed weeds before planting.*

1/ *Mention of trade names does not constitute endorsement of the products by the USDA Forest Service.*

The jack pine, red pine, white spruce, and hybrid Japanese-European larch were planted separately so comparisons among species were not part of the design. All combinations of the following container system and competition control factors were replicated by random assignment in each of four blocks:

Container	*Competition Control Treatment*
1. Large Polyloam block	Control
2. Small Polyloam block	Casoron G4 herbicide at 147 kilograms per hectare
3. Rootrainer	Casoron G4 herbicide and Roundup at 2.26 kilograms per hectare (acid equivalent)
4. 3-M polymer	Roundup at 2.26 kilograms per hectare (acid equivalent)

The pre-emergent herbicide, Casoron, was applied in bands after planting in the fall of 1974. The Roundup was applied as a direct spray in early July 1975 (fig. 3).

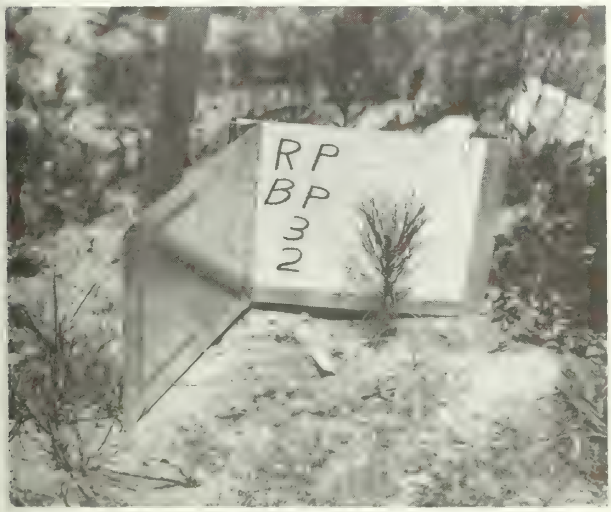
FIRST YEAR SURVIVAL

After one growing season containers had affected survival of all species. The Rootrainer and 3-M polymer survival consistently outperformed the large and small Polyloam (table 2). At present, seedlings from the Rootrainer and 3-M polymer blocks appear to perform equally well. However, differences in growth or survival may occur later. The competition control treatments also affected survival: survival was consistently lower on plots treated with Casoron (table 2).

DISCUSSION

The two container systems with the best survival--the Rootrainer and 3-M polymer block--should be evaluated further. Survival of seedlings from both systems was high enough to indicate that container planting outside of the spring planting season is possible, provided competition control (provided here primarily by site preparation) is adequate.

The lower initial survival in the plots treated with Casoron compared with the control plots was unexpected. This may indicate a toxic effect, or it may indicate that the shading by the herbaceous vegetation in the control plots provided a more favorable environment for the trees by reducing transpiration and soil moisture evaporation. The control and Roundup treatments were similar because the herbicide effect was only present during the latter part of the season. The final effect of competition control will have to be evaluated on growth and survival beyond



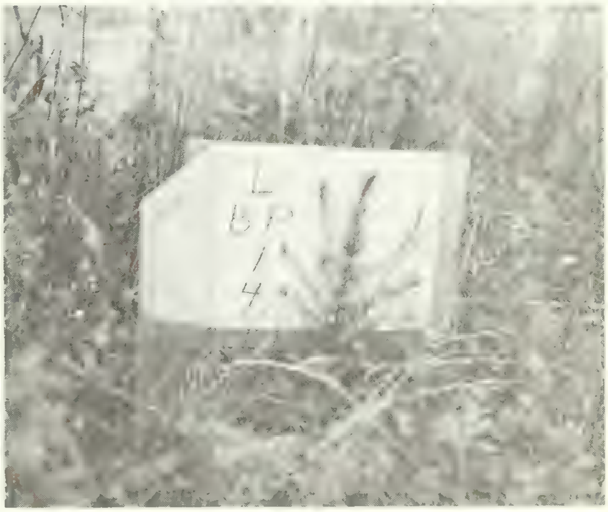


Figure 3.--*A red pine seedling on a Casoron treated plot (left), and larch on a Roundup plot (right).*

Table 2.--*Seedling survival for four conifer species by container and competition control treatment*
(In percent)

Container and competition control treatment[1]	Jack pine	Red pine	White spruce	Larch
Large Polyloam block				
Control	38	52	35	59
Casoron	[2]--	--	15	--
Casoron/Roundup	--	39	23	36
Roundup	41	34	41	67
Average	39	42	29	54
Small Polyloam block				
Control	42	44	48	52
Casoron	--	--	--	--
Casoron/Roundup	33	36	25	28
Roundup	53	33	50	59
Average	43	38	41	46
Rootrainer				
Control	97	73	88	94
Casoron	83	62	53	--
Casoron/Roundup	84	36	61	47
Roundup	91	73	87	86
Average	89	61	72	75
3-M polymer block				
Control	97	92	83	92
Casoron	88	83	--	--
Casoron/Roundup	83	75	45	44
Roundup	97	83	89	95
Average	94	84	72	77

1/ There are statistically significant differences between container systems and treatments, but analysis to identify individual differences has not been run at this preliminary stage of the study.

2/ Not planted.

this initial establishment period. There is need to evaluate and develop better site preparation methods that will concentrate moisture and nutrients, especially organic matter, in the root zone of these containerized seedlings to attain truly superior growth.

FUTURE RESEARCH

Other problems to be studied include the efficiency of mixed conifer-hardwood plantations. One of the basic principles of increasing forest productivity is to quickly occupy the site with species of economic importance, such species combinations as rapidly growing *Populus* hybrids and spruce may have distinct possibilities. These plantings would have to be designed to permit mechanical harvesting of the faster growing species. We need plantations that need no noncommercial thinnings.

We are also working with the Genetics Project in learning how best to establish and grow genetically improved yellow birch, and have begun a small study to evaluate requirements for yellow birch plantations.

We anticipate finding alternatives to natural regeneration on sites cleared by the total tree harvesting systems. These sites obviously offer better opportunities for planting than the traditionally clearcut areas where slash is a problem.

Cooperative studies involving the "Engineering Systems and Mechanization for Northern Forest Stands" Work Unit at Houghton Michigan, are of special importance in this problem area. Once silvicultural research has determined the physiological needs of the seedling and the proper environment for growth, the information is of little value if the equipment required to put the practices into effect on a commercial basis is not available. Current high labor costs dictate mechanization of woods operations, and increased mechanization requires more extensive engineering. Consideration of engineering requirements together with physiological requirements for growth will enhance the potential of achieving a commercially acceptable system of establishing and managing intensively cultured planted stands.

INCREASED YIELDS OF INTENSIVELY MANAGED PLANTATIONS OF IMPROVED JACK PINE AND WHITE SPRUCE

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Increased growth resulting from provenance selection and breeding based on progeny tests and the direct use of vegetatively propagated superior individuals of white spruce and jack pine are discussed. Volume increases in provenance selection of 20-30 percent in white spruce and 10-20 percent in jack pine are expected. The direct use of cloning of superior individuals may increase the gains 100 percent in white spruce and 50 percent in jack pine provided research can develop needed techniques. Some silvicultural aspects of intensive plantation management are also considered.

Intensive plantation management is not a new concept. For many years European foresters have grown selected provenances with nurse-crops after substantial site preparation and with control of competing vegetation often using hand labor. In the United States, the system has not been used in the past.

For the purpose of this paper, we will recognize four essential elements of intensive plantation management:

1. Site selection.
2. The use of improved genetic stock.
3. The production and use of improved planting stock.
4. Site preparation and plantation establishment and maintenance, including the choice of spacing and in some cases the choice of species combinations.

This paper will primarily consider the genetic aspects of intensive plantation management and will limit itself to jack pine and white spruce. The breeding goals for jack pine and white spruce are to achieve:

1. Maximum yield of fiber in the shortest possible time commensurate with the site quality and the investment in site preparation and maintenance. We anticipate maintenance in terms of control of competing vegetation, but not control of competition between the planted trees themselves. In other words, we anticipate a management system that will not require thinning or only a minimum of thinning during the rotation.

2. Adaptation to the climate in the region.

3. Resistance to insects and diseases.

In this paper we discuss what might be achieved in a tree improvement program primarily in terms of increased growth rates or yields. The results, with one exception, represent the growth that can be achieved with genetically improved material in "good" plantations. We specifically mention a 5-year-old white spruce test, where growth may approach what can be achieved under intensive plantation management. We also attempt to estimate how close we are to the actual delivery of improved seed on a commercial scale. Finally, we suggest some stand formations that perhaps should be tested in connection with the management of intensively cultured plantations of genetically improved material.

HOW MUCH IMPROVEMENT MAY WE EXPECT?

Improvement may be achieved at three levels:

1. The use of seed collected in stands of proven genetic superiority. This process is simple and inexpensive. But often it is possible to obtain only limited improvement in this way. In most cases, however, such a program can be mounted rapidly on the basis of existing provenance tests.

2. Continued breeding programs based on progeny testing and selection require much more investment and a longer period of time to achieve improvement.

3. At present, the third method is used only for species that propagate readily from cuttings, such as poplar. It is based on the selection of outstanding individual genotypes and mass production by means of vegetative propagation. Not until recently has this technique been suggested as an approach to improving hard-to-root species of conifers. For such species the method would depend on juvenile selection and propagation of young material still within the easy-to-root age.

Use of Improved Provenances

White Spruce

The amount of improvement that can be achieved in the Lake States by selecting the best provenances of white spruce may be estimated from three studies within the region. The oldest and perhaps most reliable data are from a seed-source test of white and Norway spruce established in 1936 in northeastern Wisconsin and Minnesota with 2-2 transplants. The study has demonstrated the superior performance of white spruce material from southeastern Ontario. In the Wisconsin test, using the simple formula d^2 x height x survival as a measure of volume per plot,[1/] the collection from Douglas, Ontario, at 29 years after planting surpassed that of the local seed source from Florence County, Wisconsin, by 12 percent. Unfortunately, the local seed source was only represented in a single 100-tree plot, whereas the measurements for the Ontario seed source are based on the average from six 100-tree plots.

Assuming thinning from below, the final harvest would be based on fewer but larger trees. Therefore, it is possible that the increases in yields would be greater. Comparing the tallest one-third of the measured trees in the Ontario provenance with the tallest trees in the control-plot suggests a volume superiority of more than 37 percent Four other seed sources from the Lake States and Ontario are represented and better replicated in the test. The Douglas, Ontario source exceeded all four sources in cubic volumes per plot by 24 to 98 percent (based) on all measured trees) (King and Rudolf (1969)

In the test of the same material in northern Minnesota, the differences in height and d.b.h. between the southeastern Ontario and the local Minnesota sources are not significant. However, the Douglas, Ontario source, because it survived better, did surpass the local source by 68 percent in cubic volume per plot. Newer tests have substantiated the better performance of Ontario sources in northern Minnesota. In a test established in 1958 and measured 15 years after planting, average tree volume for the five best seed sources, all from southeastern Ontario, ranged from 0.81 to 0.94 cubic feet, whereas the control trees from three different Minnesota nurseries ranged from 0.35 to 0.63 cubic feet per tree (Stellrecht *et al.* 1974).

It would be tempting to conclude from these data that all white spruce genotypes in Minnesota are inferior and should be completely disregarded as a source of parent material in a white spruce breeding program. This is not correct, since superior individual trees have been identified in other tests. It is correct, however, to state that seedlots used in commercial nurseries in Minnesota in 1958 were of inferior quality and that the use of southeastern Ontario seed could have significantly improved the yields in white spruce plantations in the State. There is little reason to think that seed now used in the State differs greatly from the seed used in 1958.

The most recent rangewide test of white spruce has essentially substantiated the results of the older tests (figure 1). In

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1/ *A plot was 50 by 50 feet, planted with 100 trees.*

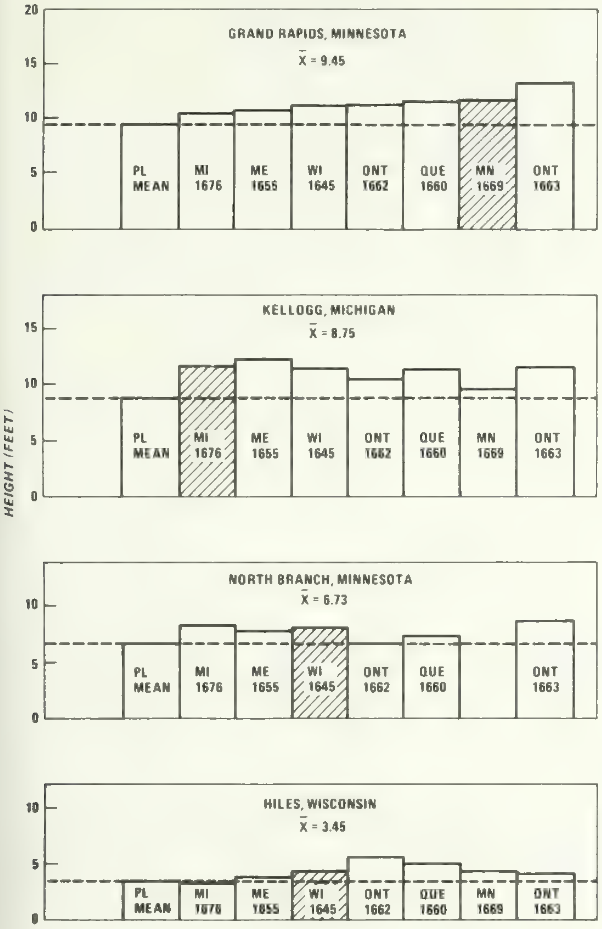

Figure 1.--*Mean heights 14 years from seed of white spruce provenances at four test sites in the Lake States. The shaded bars are the Lake States seed sources from the environments that resemble the test site the closest.*

Lake States plantings, heights of provenance material from southeastern Ontario has surpassed the growth of local seed sources by 1 to 15 percent (see also Nienstaedt 1969).

In summary, using superior white spruce provenances such as the southeastern Ontario source mentioned here, it is realistic to expect increases in height growth at midrotation from 10 to 15 percent and in volume growth between 20 and 30 percent.

Jack Pine

Gains from provenance selections in jack pine may be estimated from a test of 26 Lake States seed sources measured 20 years after planting in 15 field tests in the three States. The data from these tests are now being prepared for publication.

The preliminary volume estimates (table 1) show two important points: (1) Individual tree volumes of selected provenances exceeded the mean plantation tree volumes in 30 of 40 comparisons by 1 to 31 percent. (2) Although none of the 10 seed sources is consistently superior in all 4 tests, some seed sources are particularly noteworthy. Source 1601 from Minnesota exceeds plantation means by 7 to 15 percent in three tests and is slightly below average in the fourth, while 1617 from Michigan is 14 to 31 percent above the mean in three tests and 7 percent below in the Beltrami County, Minnesota, test. More reliable seed source selections must be based on the complete set of data, but these measurements suggest that volume increases from 10 to 20 percent may be expected on the average in jack pine through the use of the right provenances.

Use of Individual Tree Progeny Testing and Selection

White Spruce

The most detailed information on the performance of individual progenies of white spruce in the Lake States is in a test of open-pollinated progenies at Lake Tomahawk, Wisconsin (61 progenies); Wabeno, Wisconsin (39 progenies); and Moran in the Upper Peninsula of Michigan (55 progenies). There were highly significant differences between families at all three test sites (fig. 2). For example, at 9 years from seed, family 1886, selected in a plantation in Menominee County, Wisconsin exceeded the plantation mean height by 24.5, 13.3, and 14.0 percent in the Lake Tomahawk, Wabeno, and Moran plantations, respectively. Families 1886 and 2521 were common to all three tests and ranked 1 and 2, 10 and 7, and 6 and 11 at Lake Tomahawk, Moran, and Wabeno; 2517 rated 3 at Lake Tomahawk and 5 at Moran. In other words, selecting the best third of the families as the basis for a continued breeding program would have included the three families.

On the other hand, families such as 1898 and 2525 are average or below average in all of the tests. Number 1898 ranks 46th at Lake Tomahawk, 37th at Moran, and 48th at Wabeno. All of the six families are from Wisconsin stands: 1886, 2517, and 2521 were selected in a plantation in Menominee County

Table 1.--*Average individual tree volumes*[1/] *of jack pine at age 20 in four Lake States provenance tests*
(In percent of plantation mean)

Source	Lake County, Minnesota	Beltrami County, Minnesota	Marinette County, Wisconsin	Ontonagan County, Michigan
1589 MN	113	88	101	106
1596	100	114	98	105
1600	99	106	108	103
1601	115	115	98	107
1605 WI	87	107	105	113
1606	103	103	102	106
1610	103	114	95	110
1613 MI	106	93	109	106
1617	114	93	127	131
1618	88	114	102	118
Plantation mean ($ft.^3$)	0.91	0.86	1.29	1.26

1/ Volume ($ft.^3$) = $0.1174 \times 0.3453(D^2H)$.

(the original seed source probably of local Lake States origin); 1892 and 1898 are from a stand in southern Ashland County; and 2525 is from a stand in northern Ashland County, Wisconsin. All the families represent the Lake States, so the plantation means shown in figure 2 are good values to use for comparisons. The Moran, Michigan, planting, however, included an additional control, i.e., standard nursery stock from Toumey Nursery of Ottawa National Forest origin. This seed source was, at the time of establishment, used extensively for planting on the Ottawa, Nicolet, and Chequamegon National Forests. It was much below the plantation mean and was exceeded in growth by the two better families (2517 and 1886) by 56 and 49 percent.[2/] As will be mentioned later, some of the selections from Menominee County have been used in tests of controlled pollinations. They have in all instances performed well, yielding progenies superior to controls.

2/ *The difference between the control and the best families does not represent genetic differences alone, because the commercial control was raised at Watersmeet, Michigan, and not Rhinelander, Wisconsin, where all the test material was raised. The results, however, are typical of all the Work Unit's tests of jack pine and white spruce. The planting stock from Toumey has been inferior in all cases.*

Jack Pine

Information available for jack pine is not as detailed or as well substantiated as the white spruce information. Several open-pollinated progeny tests are in progress in the Lake States and will, in a few years, give us much more reliable estimates. Here we report 4-year height growth of full-sib families represented in two plantations in northeastern Wisconsin. The 2 tests have 51 families in common and are all of Lake States origin. Plantation means, therefore, are a good value to use for comparison (fig. 3). On the better site, the best of the six families exceeded the mean by 10 to 19 percent, while the superiority of these families at the poorer site was only 4 to 8 percent. The relative performance on the two sites of this limited number of families was strongly correlated. This was also the case when all families were considered.

The variability within jack pine appears to be somewhat less than the variability in white spruce. As a gross simplification, we can say that white spruce is one of the most variable native conifer species followed closely by jack pine. With this information, it is clear that the potential for genetic improvement is high in white spruce and jack pine. However, it is too early to predict the specific gains that may be achieved through selection and breeding.

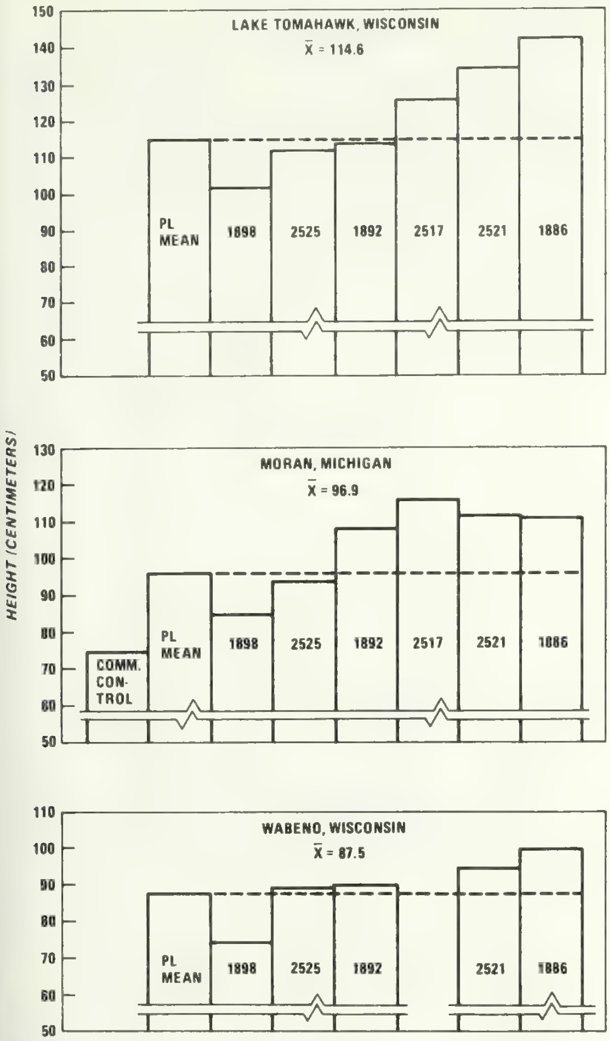

Figure 2.--*Mean heights 9 years from seed of white spruce. Progenies at three test sites in Wisconsin and Michigan.*

Direct Use of Superior Clones

Superior, individual genotypes have been used directly in some forms of plantation management using species readily propagated by means of rooted cuttings. At present, the maximum fiber yield concept is essentially based on clonally propagated material of *Populus*. Recently, a number of studies have suggested that this approach may be feasible for spruce and pine provided: (1) selections are made in juvenile material and screened for rooting ability while young, and (2) the rooting ability can be maintained by special techniques such as hedging or repeated rooting. The Genetics Work Unit is studying both the physiological and the genetic aspects of the problem.

White Spruce

The use of juvenile selections as an approach to tree improvement has been questioned in the past. The following is offered as evidence of its possible usefulness with white spruce: about 700 white spruce seedlings were selected for superior height in nursery beds in a northeastern Wisconsin nursery. They were paired with immediately adjacent average seedlings and planted in the field. After 22 years from seed, the selected seedlings still exceed the control plants in height by more than 27 percent. With this information, an increasing effort has been made to select superior juvenile spruce. The following test is an example:

In a well replicated test of controlled pollinated progenies of Menominee, Wisconsin, white spruce, 32 trees exceeding 160 centimeters (5¼ feet) were selected in four of the best families at age 5 (fig.4). Three control populations were included in the test: 1645, a stand collection from near Monico, Wisconsin; 4485, a Nicolet National Forest

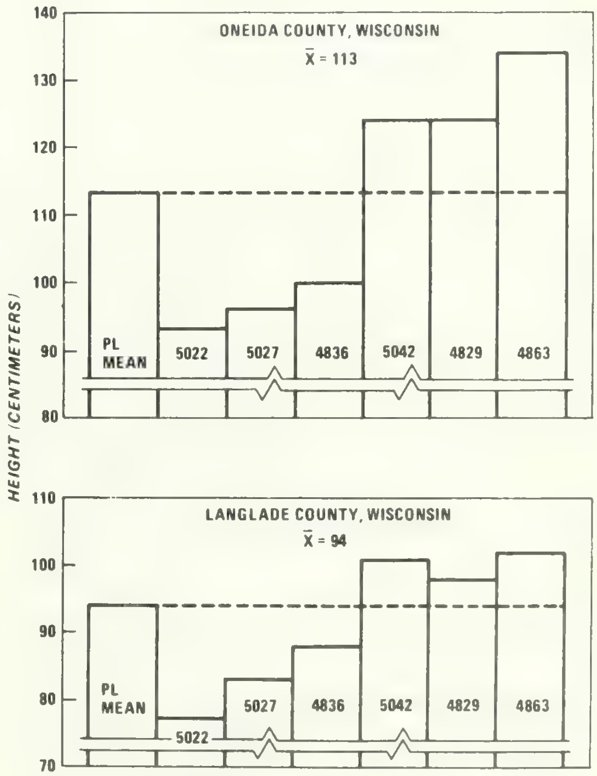

Figure 3.--*Mean heights 4 years from seed of jack pine progenies at two test sites in Wisconsin.*

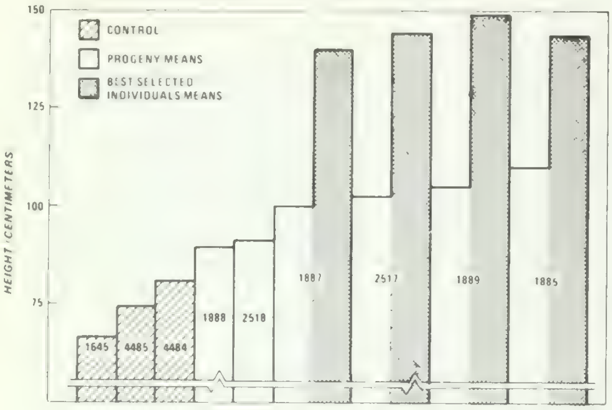

Figure 4.--*Mean heights at age 5 from seed of best selected white spruce individuals compared with the mean heights of the sibling progenies and of control populations.*

area collection; and 4484, seed from the Oconto River white spruce seed production area. The means of the four best families exceeded the controls in height by 23 to 61 percent. (Note that the best control, 4484 from a white spruce seed production area, exceeds the "commercial" area collection (4485) by 9 percent.) In comparison, the average heights of the best individuals of the same four families exceed the controls by 104 to 154 percent.

Thirty of the selected trees have been screened in a preliminary test for their ability to root. Although it was impossible to maintain optimum rooting conditions throughout the test, rooting exceeded 30 percent in 10 of the 30 trees and 80 percent in one tree. Future tests must verify the rooting ability and the superior growth must be thoroughly tested in properly designed replicated clonal tests. If the work is successful, it is clear that gains approaching 100 percent may be achieved in white spruce cheaply and quickly.

This test was established with containerized stock at 2 by 2 foot spacing and maintained essentially weed-free. Water levels were optimized during the growing seasons, but nutrient levels were not optimum throughout the 5 years of growth. The tallest trees exceeded 180 centimeters (6 feet) in height 5 years from seed and the best family averaged 110 centimeters (almost 4 feet). This probably approaches the performance of the intensively managed plantations of the future.

Jack Pine

In a similar test the five best full-sib jack pine progenies out of more than 70 families exceeded plantation mean height by 9 to 19 percent (fig. 5). Height superiority of the five tallest individuals within the same five families ranged from 26 to 33 percent.

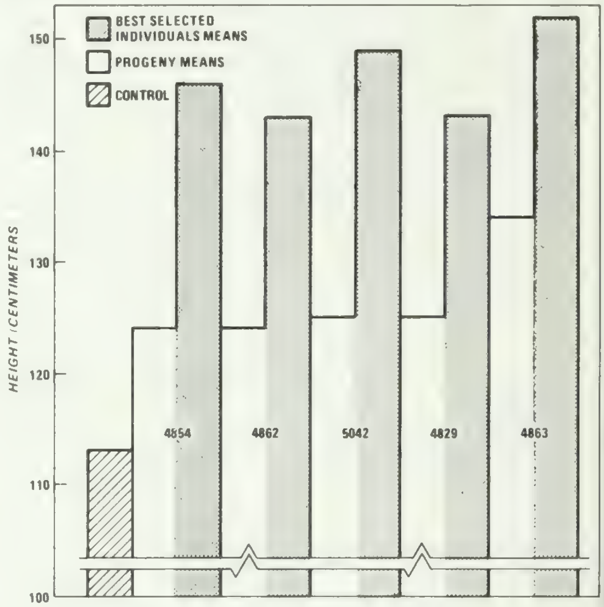

Figure 5.--*Mean heights at age 4 from seed of the five best selected jack pine individuals compared with the mean heights of the sibling progenies and of a control population.*

It should be pointed out that whereas the spruce families resulted from controlled pollination with pollen mixtures of eight trees, the jack pine families involve full-siblings involving a mother tree and a single male parent. This, of course, would tend to reduce variability in the jack pine families.

As previously mentioned, jack pine appears to be less variable than white spruce at the family level. On the basis of the above discussion, it is probably also reasonable to state that the within-family variaticn is less in jack pine than white spruce. Even so, jack pine is endowed with great potential for genetic improvement.

HOW SOON WILL IMPROVED GENETIC MATERIAL BE AVAILABLE?

Seed production areas are considered an interim phase of tree improvement that will

assure seed of known origin, good physiological quality, and, in some cases, possible small genetic gains. As mentioned, seed from the Oconto River Seed Production Area in one test has demonstrated 9 percent superiority over area collections at age 5. Seed from the other National Forest white spruce seed production areas has not been tested but has performed well in the nurseries. The seed production areas, in fact, are so productive that the Wisconsin Department of Natural Resources is considering obtaining excess seed from the two Wisconsin areas for the State nurseries. All white spruce planting stock used in the National Forests in the Lake States today is raised from seed production area seed.

White spruce seed orcahrds have been established by Region 9 and are beginning to produce modest amounts of seed. Within the next 5 years, production should increase greatly, and within 10 years, we can expect all white spruce seed for National Forest use to be produced in seed orchards. We cannot yet estimate the gains that might be achieved in the orchards, because all the parents in the orchards have not been progeny tested. We expect the improvement to exceed that for seed production areas, but we cannot expect gains of more than 20 percent until the orchards have been rogued on the basis of progeny tests.

Small amounts of seed from controlled crosses of known high quality genotypes representing the quality seed that can be expected from continued breeding programs are now available from the Genetics Work Unit. The crosses are being repeated annually and seed can be made available to cooperators for testing in plantings from one to a few acres in size. On the basis of early growth, they represent improvements of 25 to 50 percent.

A small experimental seed orchard representing the best available genotypes will be established by Region 9 in 1977. The orchard will start producing seed almost immediately, and by the mid-1980's should produce tens of thousands of seed annually. However, because of the rather narrow genetic base of the parent material, the seed is not intended for any extensive planting program.

The use of clonally propagated superior white spruce individuals is some years in the future. We will continue screening the 32 juvenile selections we have for rootability. If we manage to successfully root any of these, a number of re-rooting cycles will be necessary to build up enough stock plants to make seedlings available in sufficient numbers for commercial planting operations. Thereafter, it will be necessary to develop methods for maintaining the rootability of the selected clones. If we succeed all along the way, hundreds of thousands of seedlings should be produced annually early in the 1980's. Meanwhile, the search for and screening of superior juvenile white spruce should be continued.

Improved jack pine is not now available in the Lake States. However, the State of Minnesota in 1975 began to convert a proven stand into a seed production area. Based on the 1954 Lake States jack pine seed source study, this superior stand was selected at St. Croix Park in Minnesota. Roguing started in 1975, so the first seed representing any degree of improvement should be available for collection in 1977. A gradual up-grading of the stand will be achieved as trees are removed for seed harvest.

This source of seed will be perpetuated and improved through replanting in the area with the same provenance and by continued selection for growth rate and quality. Modest increases in yield from 5 to 8 percent may be achieved from this area.

The Michigan Department of Natural Resources and Michigan State University cooperated in establishing seed orchards with open-pollinated jack pine progeny. The Potlatch Company in Minnesota established an orchard in 1974 and in 1975 Region 9 established tests to be converted into seedling seed orchards. Modest amounts of seed can be expected from such orchards in 6 to 8 years. Yield increases from 15 to 25 percent may be achieved through an approach combining the best provenances with the best genotypes within provenances in the orchards. Subsequently, from 5 to 8 percent more improvement may be achieved per generation of future breeding (King 1973).

Jack pine improvement based on clonally propagated superior individual trees probably will present more of a problem than white spruce. Although the species roots readily from cuttings in the juvenile stage, it will probably take longer to build up a base population from which cuttings can be obtained for mass production. This is because the crown structure of jack pine probably would not permit as severe pruning as

might be used on white spruce. However, rapid cloning of jack pine may be possible if an efficient technique for rooting needle fascicles can be developed.

HOW TO USE IMPROVED JACK PINE AND WHITE SPRUCE

It was emphasized earlier that intensive plantation management must assure planting of improved genetic stock on the best possible sites; use of improved planting stock; and site preparation, establishment, and maintenance commensurate with the management objectives. Management systems and planting sites would differ for the two species.

For jack pine, coarse sandy soil should be avoided and planting concentrated on sandy loams (Wilde *et al.* 1966). Spacing should be close and no thinning should be done. Research is needed to determine what the optimum spacing should be in stands of improved material harvested in a single cut.

We recommend that mechanical harvesting systems be developed and research done to eventually permit whole tree utilization. It does not seem worthwhile to consider species combinations as a possible approach to jack pine management. Although poor form may not constitute a serious problem with whole tree utilization for fiber, we suggest that some research in the future be conducted on the development of acceptable control methods for the insects and diseases that are the principle causes of poor form in jack pine.[3/]

White spruce is a more tolerant species and, because of its susceptibility to late spring frosts, may be a candidate for culture in combination with other species. The management objective for white spruce might be either the production of fiber alone, or the production of both fiber and quality logs for veneer or lumber; this would require two different management systems. Fiber production alone should be done without thinning; in plantings combining the two objectives, it would be desirable to keep thinnings to a minimum. If possible, a single operation to remove wood for fiber would be followed 20 to 30 years later by the harvest of logs in a single operation.

Reducing damage from late spring frosts using nurse-crops presents a research challenge. The ideal nurse-crop would be a readily established species that grows rapidly for 7 to 10 years and then disintegrates without damaging the underplanted spruce. Short of this utopian picture, we might strive towards a nurse-crop readily harvested after 10 to 12 years yielding quality products readily marketable. Other characteristics of the ideal nurse-crop would be a light density crown high up on the stem and a complete absence of root or stump sprouting. Nitrogen fixation would also be desirable. Some possible candidates for nurse-crops (not necessarily meeting all the characteristics of the ideal) would be *Larix, Alnus glutinosa, Alnus incana, Betula papyrifera* (conceivably with figuration of the wood desirable for speciality items such as turned products), *Prunus serotina, Prunus pensylvanica* and probably many others.

In the past we have accepted the results of bare root planting primarily because it was possible to achieve high survival easily for jack pine and with little care for white spruce. Success of establishment has been evaluated almost exclusively on the basis of survival. This is not acceptable when genetically improved material is used. High survival and immediate resumption of optimum growth rate are essential. To achieve this, we suggest research must develop acceptable methods to produce containerized stock and control competing vegetation. The goal of containerization has been to develop stock plants in the shortest possible time at the closest possible spacing. Economy of production has been emphasized. In intensively managed plantations of the future we suggest that the evaluation not be based on economy of stock production, or of site preparation, or of plantation maintenance, but on the total economic picture from the time seed is collected until the final product emerges from the mill.

3/ *Currently, because of the numerous insects damaging jack pine and the lack of positive correlation between the infestation responses of the different insects, we don't see any gains within a reasonable time from a breeding program emphasizing pest resistance.*

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PROPAGATION RESEARCH IN THE ESTABLISHMENT OF MAXIMUM YIELD PLANTATIONS

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The advantages of containerized plant materials in establishing intensive culture plantations are briefly described. Environmental factors that can be used to manipulate plant growth during the production phase are outlined and examples from the literature are given to show how they might be used to improve plant performance in the field. Results of some plant propagation studies underway in the Maximum Yield Project are summarized and a direction for future research is proposed.

Establishing intensive culture plantations is expensive, especially when improved plant materials are used. Therefore, practices that ensure the best possible survival and growth of seedling and cutting material will be of critical importance in obtaining maximum yields and returns from these plantations.

Containerized seedlings or cuttings show great promise in the establishment of these plantations. Many types of containers have been developed. Some are made of nondegradable plastic from which the seedling may or may not be removed before planting; others are biodegradable plastic or other material that remains with the seedling; still others consist of a block of molded or compressed materials with no actual container walls (figs. 1 and 2). Procedures for growing these seedlings vary, but commonly employ controlled environmental conditions (temperature, light, water, and fertilizer) in a greenhouse.

The most obvious advantage of this type of planting stock is that it can be transported and planted with minimum disturbance or damage to its root system. Survival and early growth should be better than for bare-root stock, especially when planting conditions are unfavorable. Thus, planting need not be limited to only a short period in the spring or fall.

As important as the container itself may be, it is only one of many important parts of the entire system. Plant materials

Figure 1.--*Pine seedlings growing in two typ of biodegradable containers--an experimental plastic (center) and paper (left and right).*

Figure 2.--*Four-month-old jack pine seedlings raised in a greenhouse in a nondegradable plastic container that may be opened to remove seedlings before planting.*

of the proper genetic origin must first be selected and the correct environmental conditions provided during the production phase. The control of the environment at this stage offers perhaps the greatest opportunity for obtaining the full potential from these selected plant materials.

By manipulating certain environmental factors both the physical components and physiological state of seedling growth may be modified. For example, seedlings may be caused to enter a state of temporary (quiescence) or permanent (rest) dormancy by regulating such factors as water, nitrogen, temperature, and photoperiod. By imposing the proper degree of dormancy on the trees before outplanting, their resistance to adverse conditions of the planting site will be increased and their establishment facilitated (Etter 1972, Tinus 1972). Relations have also been found between the nutritional status of the seedling and its ability to withstand low temperatures and perhaps drought conditions after outplanting.

Susceptibility of seedlings to frost and drought damage can be decreased by applying various amounts of nitrogen, potassium, or phosphorus to different species of conifer seedlings in the nursery (Benzian 1966, Shirley and Meuli 1939). Growth retardants may also prove useful in hardening plant materials if applied in the proper amounts and at the proper time (Irving and Lanphear 1968).

Seedling growth may also be influenced by altering one or more of the above-mentioned environmental factors. Extended photoperiods can accelerate shoot growth and increase leaf production. Increasing the light intensity may increase lateral branch production and dry weight of shoot and root. Elevated carbon dioxide levels can increase shoot length as well as dry weight. The predominantly "red" quality of fluorescent lighting produces "stocky" growth whereas incandescent light with a greater proportion of "far-red" promotes stem elongation. Response to any of these factors will in most cases depend upon the balance or levels of the other factors (Larson 1974).

In addition to evaluating several promising types of containers (refer to article by Phipps and Noste in these proceedings), we have been investigating the effects of various "soil" mixes or growing media on the growth and outplanting performance of several conifer species. Horticulturists, who have been using containerized plants for years, have done much research on the effects of the medium on the early phases of plant growth. But, until recently, studies involving tree seedlings or cuttings for forest plantings have been few.

In the early 1970's we compared the effects of various growing media on containerized red pine and white spruce seedlings (Phipps 1974). Significant differences in growth due to the media were found after 5 months in the greenhouse and, in a later outplanting test, these differences were found to persist even after 2 years. The best medium had a pH of 5.5 and high cation exchange and moisture-holding capacities. However, the lack of close correlation between these properties and seedling growth in the other media indicated the influence of other factors that would need identification before an optimum "mix" could be prescribed.

Similarly, research is needed to determine how factors such as those mentioned above may be used to improve the propagation and establishment of plantations of selected clonal material by cuttings. Many of these factors are known to affect rooting performance of cuttings, both before as well as after the cuttings are taken from the stock plant. Rooting of softwood cuttings of some *Populus* clones in commercially

manufactured containers has proven to be a reliable method for the establishment of Maximum Yield Project research plots. However, the rooting performance of the different clones is highly variable, and a particular propagation technique or method may not be suitable for all clones. We found in a recent study that various rooting media (consisting of different proportions of sand, peat moss, and vermiculite) affected both the rate and the form of rooting.

Containerization of hardwood cuttings also appears to be a promising method for plantation establishment. One method of containerization we are studying involves molding a block of rooting medium and a plastic polymer around the cutting (fig. 3). After rooting has taken place the cutting is planted with its block.

Figure 3.--*A* Populus *hardwood cutting rooted in a block molded from peat moss, sand, and a plastic polymer.*

Although we may be able to manipulate plant growth and produce seedlings with certain measurable characteristics, we cannot yet predict with any certainty whether a particular type or "quality" of plant will survive or grow better than a plant with different characteristics. Several criteria, such as overall size of the seedling, stem diameter, ratio of top and root dry weight, have been used with partial success for many years to predict seedling performance after planting, but beyond this our judgment of seedling vigor is largely subjective. Until we are better able to define and promote the physiological factors responsible for seedling vigor, we must rely on empirical trials and attempt to correlate measurable seedling characteristics with good field performance.

Evaluation of various container systems for both seedlings and cuttings will be continued with emphasis on studies to determine the principal environmental factors that will produce plants of superior vigor and favor their establishment. When these factors have been determined for various species, intensive culture plantations can then be established on a prescribed operational basis.

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EPIDEMIOLOGY AND IMPACT OF <u>MELAMPSORA MEDUSAE</u> LEAF RUST ON HYBRID POPLARS

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Melampsora medusae *leaf rust began from aeciospores on larch (*Larix laricina*) in late May at Rhinelander, Wisconsin. Uredospores were present in large numbers after mid-July. At Rosemount, Minnesota, and Ames, Iowa, primary infection was from airborne uredospores from the north and large numbers of uredospores were found a month later than at Rhinelander. Host infection was correlated with spore trap data at three locations. Height growth was only slightly affected by rust infection, but basal diameter growth was reduced about 20 percent in a moderately resistant clone due to rust.*

Melampsora medusae Thüm is the most common native leaf rust of poplars in the United States and Canada east of the Rocky Mountains. It is a long cycle rust with alternate hosts: *Larix* spp. (especially *L. laricina* (Du Roi) K. Koch) and *Populus* spp. It has been found on all native and introduced poplars grown within eastern North America (Arthur and Cummins 1962).

Rust infection begins in the early spring, soon after the new larch needles begin to elongate. However, larch needles are susceptible to infection for only a short time, and because aeciospores of *M. medusae* formed on larch infect poplars but cannot reinfect other larch, this rust probably does little damage to larch.

In contrast, uredospores produced on poplar can reinfect other poplar trees throughout the summer, and serious epidemics of leaf rust can occur on susceptible poplars. Although larch does not occur naturally very far south of the Great Lakes (Little 1971), spores from infected poplars within the range of larch are wind disseminated, and poplars as far south as the Gulf of Mexico become infected each year (Filer 1975).

Because rust on poplars is confined to leaves, any damage to trees will be caused by leaf damage and defoliation (Schipper and Dawson 1974). Severely rusted poplars are known to be more susceptible to other diseases (Meiden and Vloten 1958). Rust on other species increases winter injury (Kessler 1970), but how much growth is lost due to poplar leaf rust has not been reported.

To determine the type of inoculum causing primary infection of poplars and to follow the buildup of rust, we monitored numbers of aeciospores and uredospores in relation to date, weather, and host development at Ames, Iowa; Rosemount, Minnesota; and Rhinelander, Wisconsin. To evaluate the effect of leaf rust on growth and ultimately on yield of usable wood of poplars, we measured growth of hybrid poplars in plots at Rhinelander and Rosemount.

MATERIALS AND METHODS

Epidemiology

Six vaseline-coated microscope slides were exposed horizontally as spore traps at each location. Slides were retrieved weekly, stained with acid fuchsin in lactophenol, and examined for aeciospores and uredospores

of *M. medusae*. The number of spores of each type was counted in three passes at X250 magnification with a microscope across separate widths of each exposed spore trap.

Larch and poplar at Rhinelander were examined every other week during the spring and early summer for *M. medusae* infection and plant development. Rhinelander is the only location sampled that is within the natural range of *L. laricina*.

Measurement of the Poplar Host

The clones used in this study were NC 5261 (*Populus deltoides* x *P. balsamifera* 'Northwest'), NC 5339 (*P. alba* x *P. grandidentata* 'Crandon'), and NC 5377 (*P.* x *euramericana* 'Wisconsin No. 5'). At Rhinelander, NC 5339 is highly resistant to leaf rust, NC 5377 is moderately resistant, and NC 5261 is highly susceptible (Dawson 1974).

Plots were established at each location using a modified Latin square design, with five rows of five plants each and surrounded by two rows of buffer trees to reduce edge effects. Plots were planted at a stocking density of 10,000 stems per ha. Four replications of the basic plot were established at each location: two replications were treated with the fungicide maneb-Zn every other week to reduce or exclude rust; the other two replications were left unprotected.

In early June, late July, and early September of 1975, each plant in the plots was measured for growth and rust severity. Values recorded were total height, basal stem diameter, and number of leaves. Rust severity was estimated according to Schreiner (1959). Briefly, rust infection on leaves was estimated as light, medium, or heavy and given a numerical value of 1, 5, or 25, respectively. Then the percent of the leaves rusted was estimated at less than 25, 26 to 50, 51 to 75, or greater than 75 and given a numerical value of 1, 2, 3, or 4, respectively. Multiplication of the two numerical values gave a rust severity rating (RSR) of from 0 (immune) to 100 (very highly susceptible).

RESULTS

At Rhinelander, the larch leaves first appeared between April 30 and May 5. Poplar leaves first appeared about May 10, and first leaves were fully expanded by May 21. Aecia were found first on larch needles on May 19, and aeciospores were found on exposed spore traps during the following week (fig. 1). Aeciospores were found on spore traps between May 25 and July 1.

Uredial pustules first were observed on poplar leaves on June 16 and thereafter throughout the summer until defoliation in the fall. On spore traps, a few uredospores were found during the week ending June 2. Uredospores were not found again until the week ending June 23. Uredospore numbers were small until July 14, after which numbers of spores increased rapidly and remained large until after September 15.

At Rosemount, no aeciospores were found on spore traps (fig. 2). Uredospores first were found in small numbers during the week ending July 6, and numbers remained small until the week ending August 18. Uredospore numbers were large until the week ending September 23, after which the spores were found in small numbers, even though leaves remained on some clones until early November.

At Ames, uredospores first were found during the week ending June 23, were absent for 2 weeks, and then were present in small numbers again in July (fig. 3). However, large numbers of uredospores were not present until August 18, and the most uredospores were found in September, remaining abundant until the middle of October.

No rust was found on leaves of NC 5339 in the plots at Rhinelander or Rosemount, although older trees of this clone planted elsewhere at Rhinelander did become lightly rusted late in the growing season (figs. 4 and 5). No differences were found in number of leaves, height, or basal diameter at either Rhinelander or Rosemount for this clone.

Leaves of NC 5377 were lightly rusted at Rhinelander in late July (fig. 6). By September, rust on unsprayed leaves developed to a severity of RSR 28, while sprayed leaves were rusted to a severity of RSR 12. This amount of rust caused premature defolition of unsprayed plants and reduced both height growth and basal stem diameter growth of unsprayed plants.

At Rosemount, no rust was found on leaves of NC 5377 until August, and by September, unprotected plants were rusted to RSR 10, while protected plants were rusted only to RSR 2 (fig. 7). This small amount

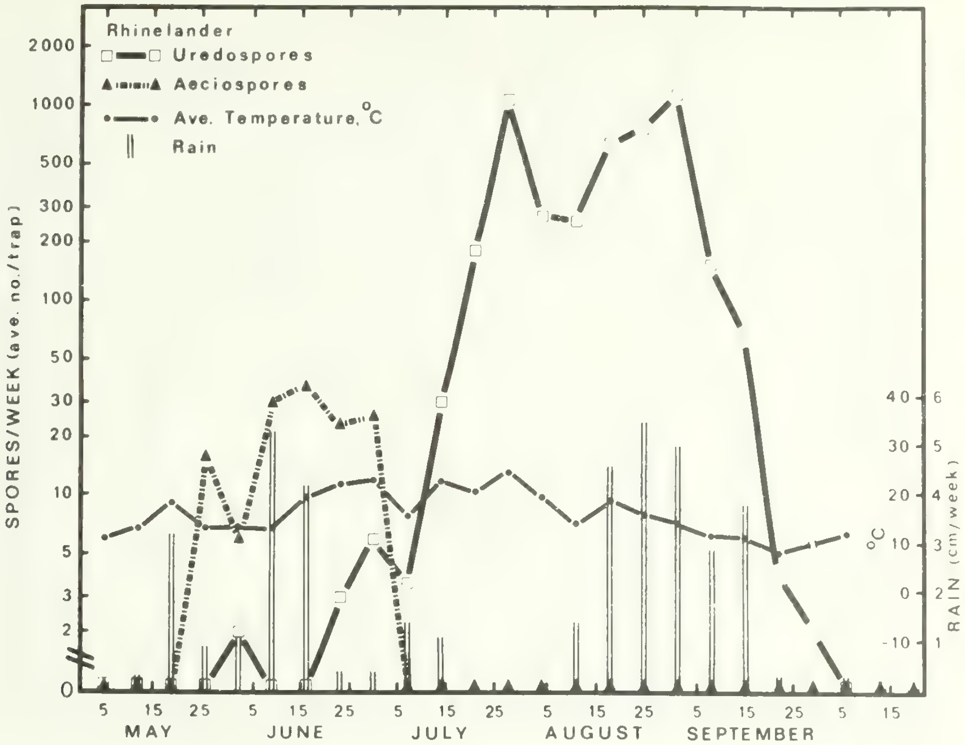

Figure 1.--*Average number of aeciospores and uredospores collected on slide spore traps at Rhinelander, Wisconsin, during the growing season of 1975.*

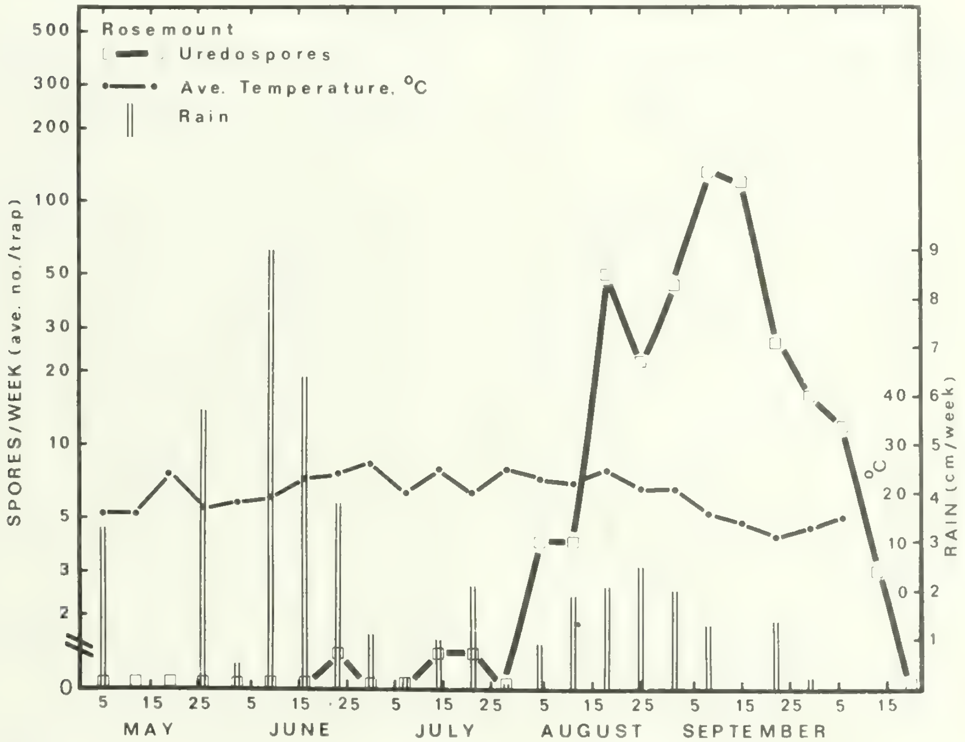

Figure 2.--*Average number of uredospores collected on slide spore traps at Rosemount, Minnesota, during the growing season of 1975.*

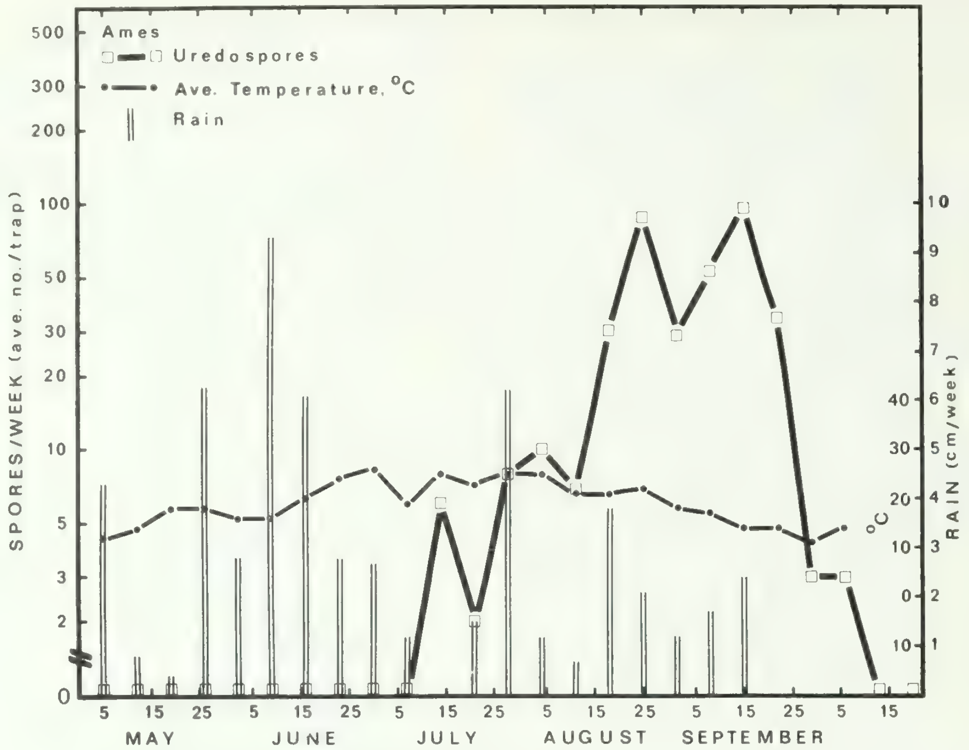

Figure 3.--*Average number of uredospores collected on slide spore traps at Ames, Iowa, during the growing season of 1975.*

of rust did not have a significant effect on leaf retention, height, or basal diameter, although basal diameter seemed to be less in unprotected plants.

Unprotected leaves of NC 5261 at Rhinelander had a rust severity of RSR 19 by the end of July, whereas sprayed leaves had a severity of only RSR 3 (fig. 8). Rust infection was severe on both protected and unprotected plants after July, so that in September, unprotected plants had a severity rating of RSR 100, while protected plants had a rating of RSR 91. The same sort of rust development took place at Rosemount (fig. 9). At Rhinelander, unprotected trees of NC 5261 had lost 47 percent of their leaves by September, while protected trees still retained almost as many leaves as in July. Unprotected trees were slightly, though not significantly, taller than protected trees and only a small difference was found in basal diameter. At Rosemount, where both protected and unprotected trees of NC 5261 became heavily rusted, defoliation by September was 83 percent for unprotected trees and 65 percent for protected trees. Height and basal stem diameter were affected by the rust in both treatments, but because the fungicide treatment offered some protection, treated trees grew significantly taller and had greater basal diameters.

The plot at Ames was destroyed by a flood of the Skunk River in June of 1975.

DISCUSSION

The epidemiological studies showed that rust infection on poplars at Rhinelander, and by extension anywhere within the geographic range of eastern larch, began from aeciospores formed on larch needles and became severe early in the growing season. At Rosemount and Ames, severe rust infection did not occur until a month after it began at Rhinelander, apparently because rust infection did not begin until uredospores from the north arrived at Rosemount and then at Ames. This delay is possibly one of the reasons that clones at Rosemount grew taller than those at Rhinelander, even though the latitude and average temperature were similar. Other factors, such as soil type, fertility, and rainfall, may also have accounted for some of the difference in height.

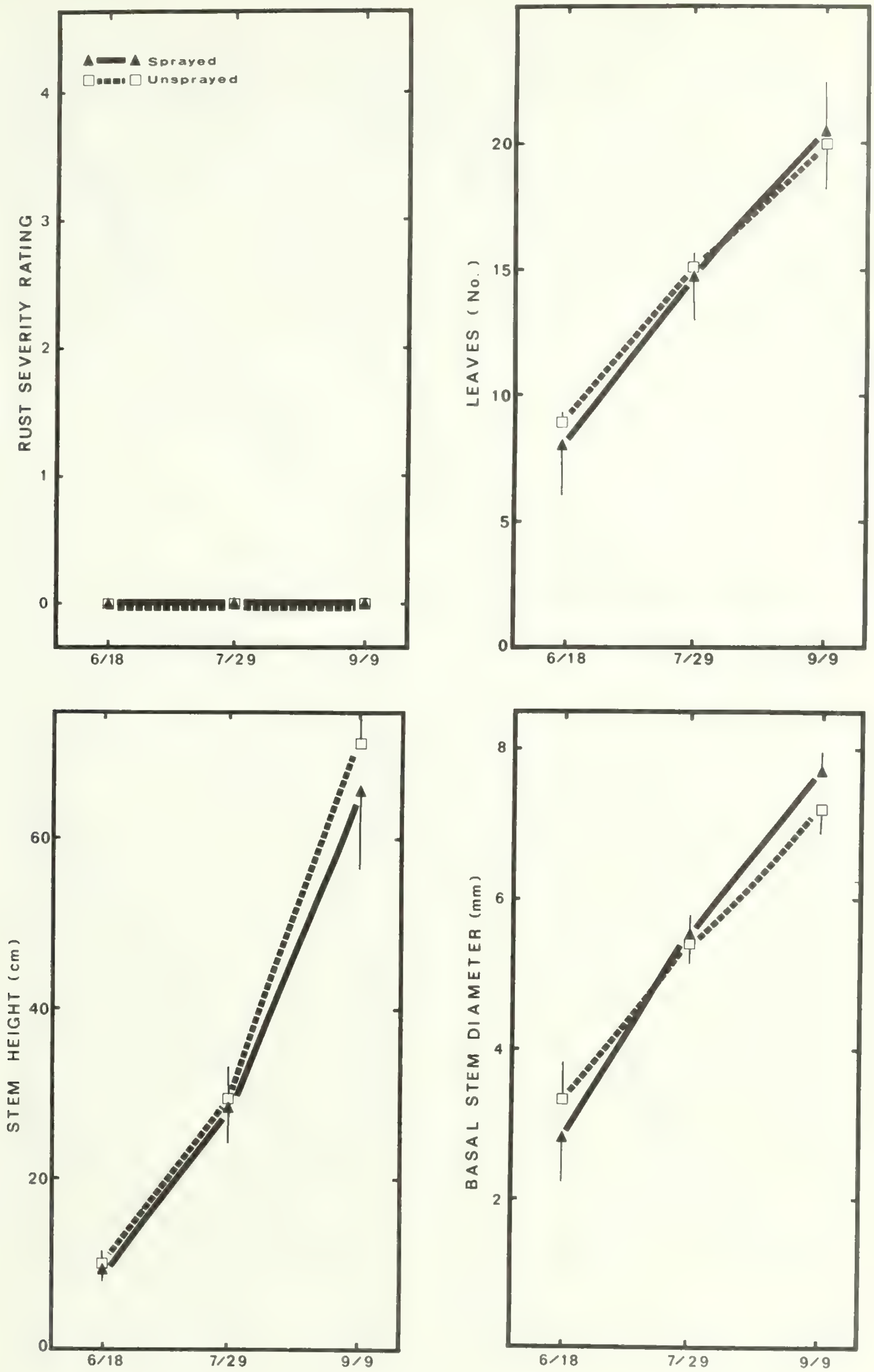

Figure 4.--*Rust severity rating, number of leaves, stem height, and basal diameter of protected and unprotected trees of clone 5339 at Rhinelander, Wisconsin.*

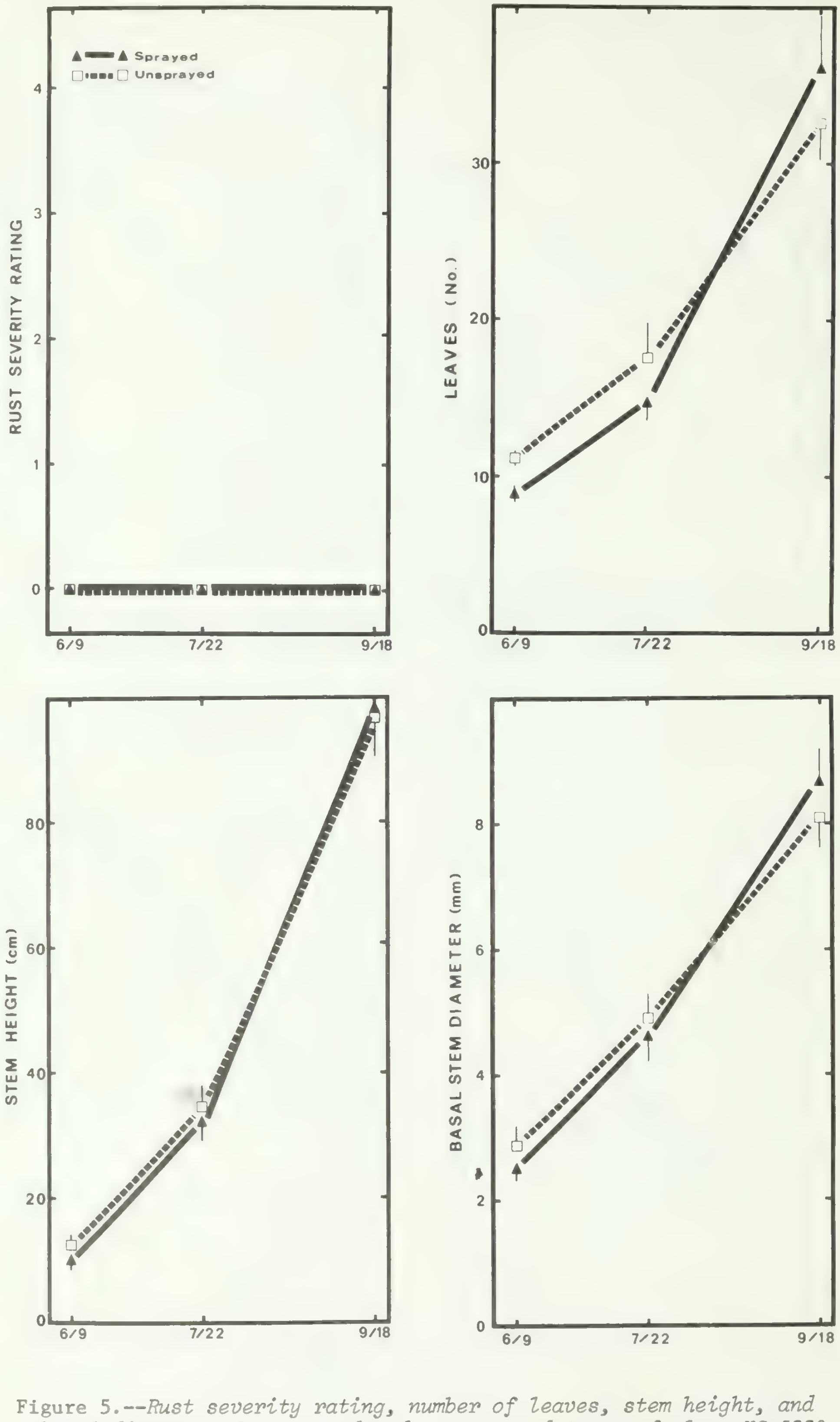

Figure 5.--*Rust severity rating, number of leaves, stem height, and basal diameter of protected and unprotected trees of clone NC 5339 at Rosemount, Minnesota.*

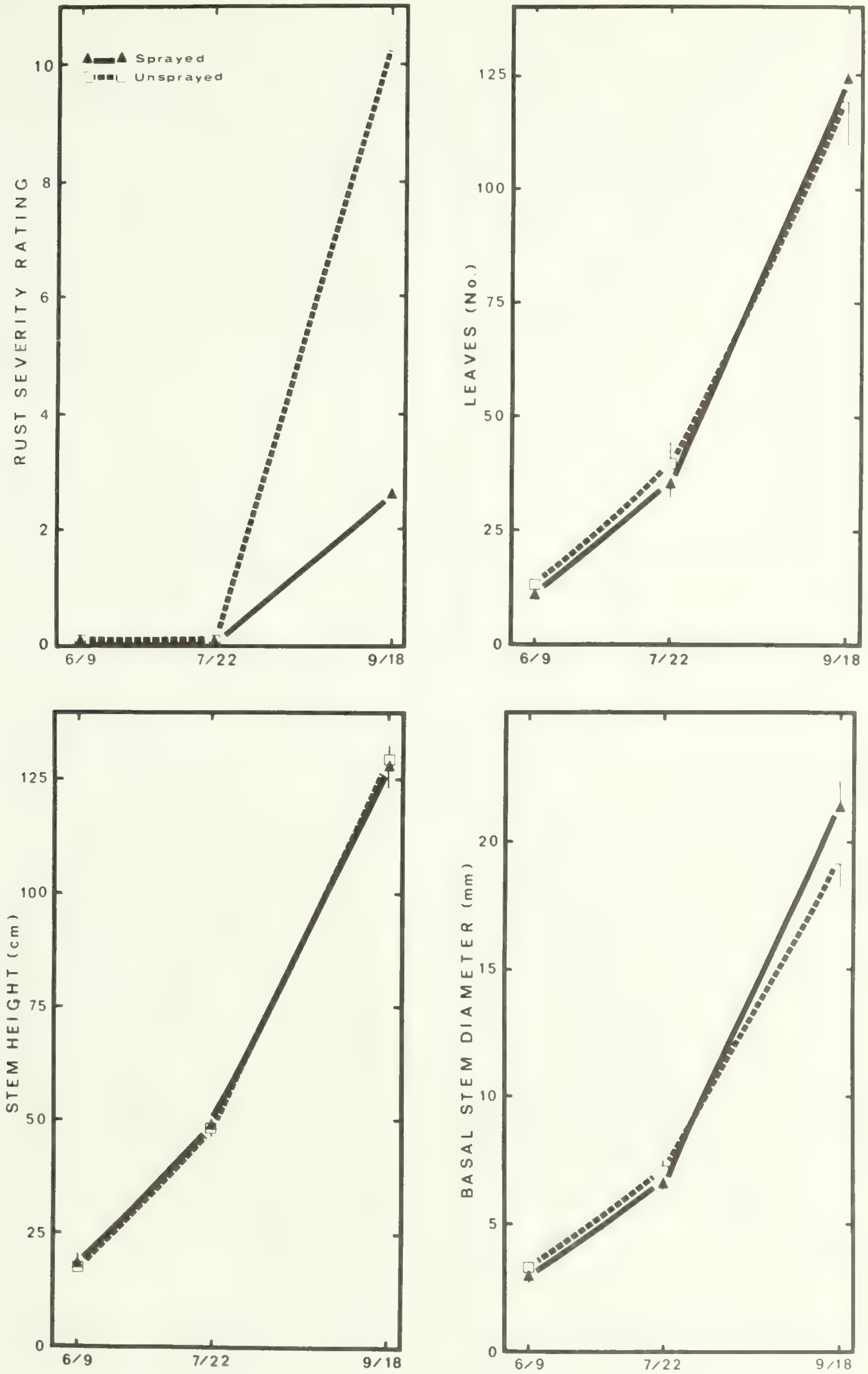

Figure 6.--*Rust severity rating, number of leaves, stem height, and basal diameter of protected and unprotected trees of clone NC 5377 at Rhinelander, Wisconsin.*

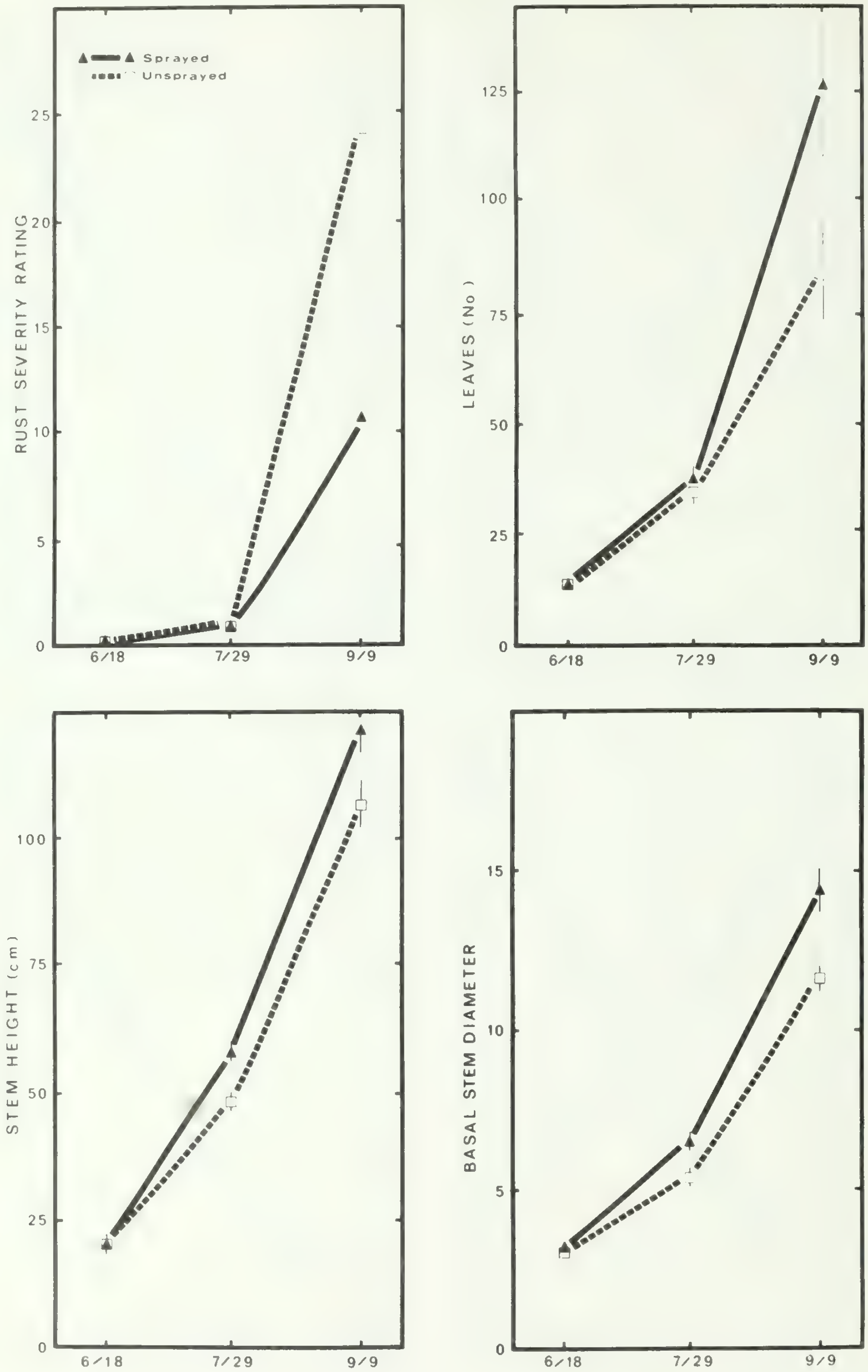

Figure 7.--*Rust severity rating, number of leaves, stem height, and basal diameter of protected and unprotected trees of clone NC 5377 at Rosemount, Minnesota.*

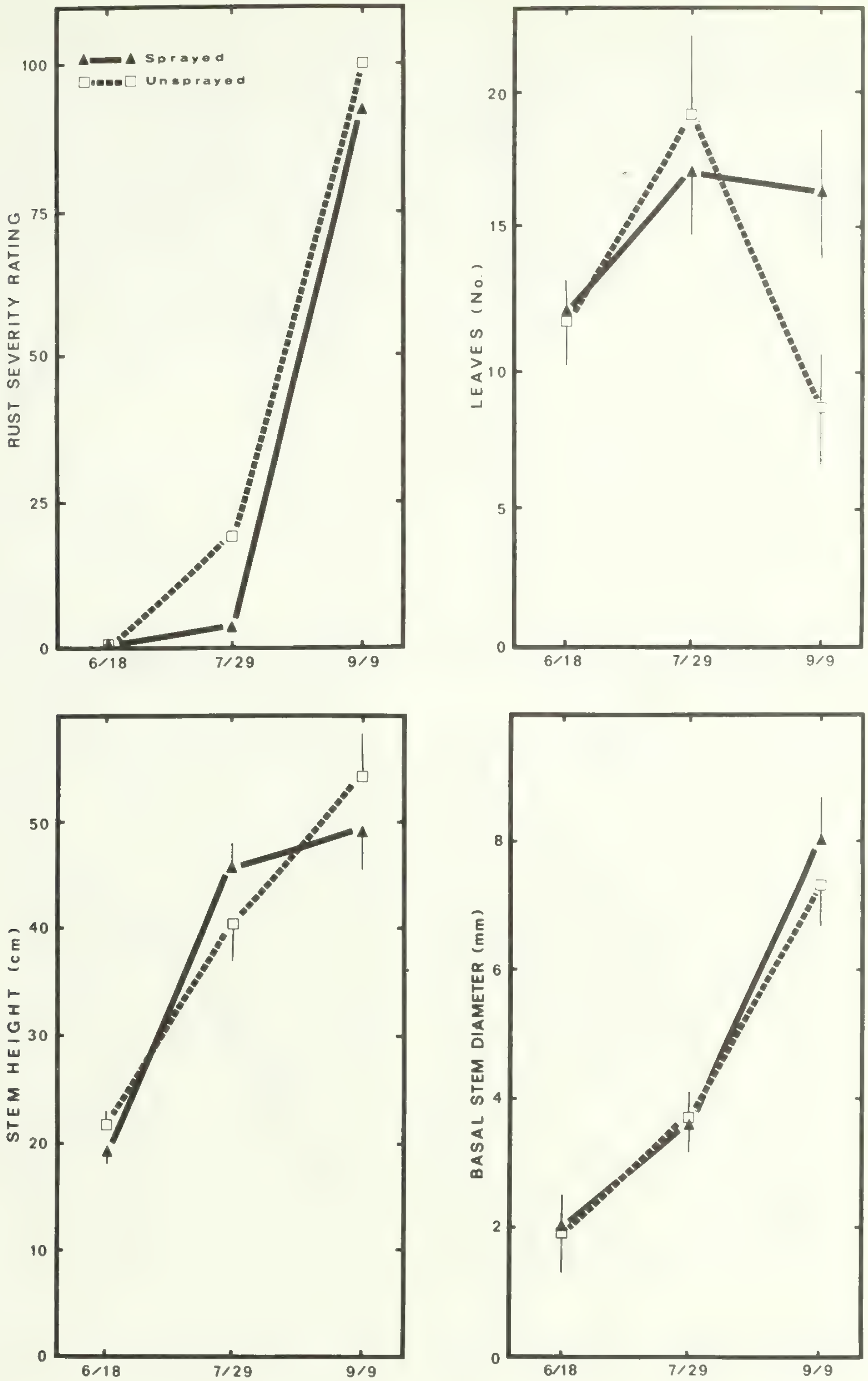

Figure 8.--*Rust severity rating, number of leaves, stem height, and basal diameter of protected and unprotected trees of clone NC 5261 at Rhinelander, Wisconsin.*

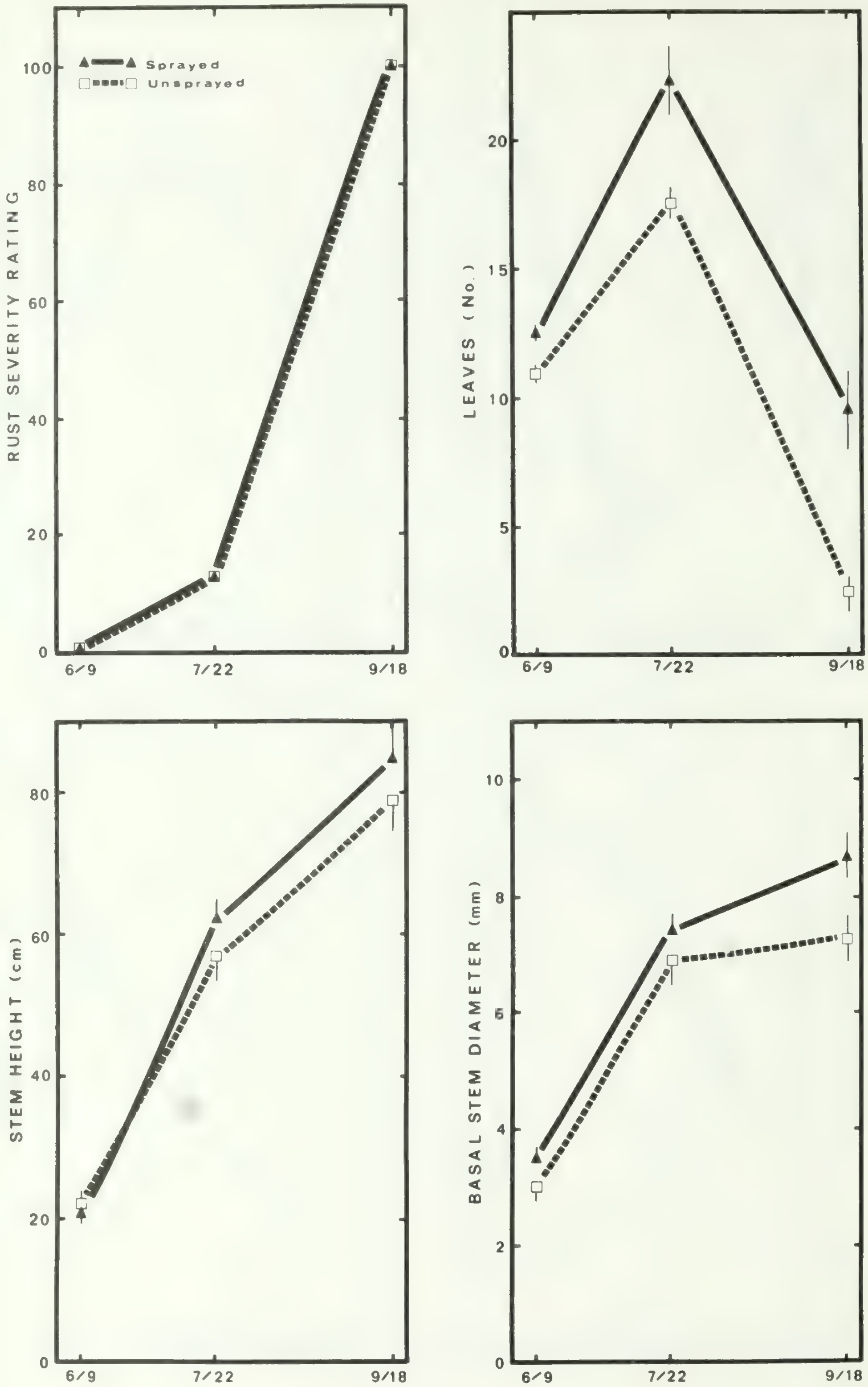

Figure 9.--*Rust severity rating, number of leaves, stem height, and basal diameter of protected and unprotected trees of clone NC 5261 at Rosemount, Minnesota.*

Although leaves of all ages can become infected, infection in nature is usually more severe on lower leaves than on upper leaves. (See Schipper article on p. 81.) Even though the trees in this study were spaced far apart, lower leaves still were more severely infected, primarily because they developed earlier and were exposed to uredospores for a longer time. Donnelly (1974) has shown that the upper portion of poplar stems is supplied with photosynthate by upper leaves, whereas the lower parts of stems are supplied by lower leaves. Therefore, loss of lower leaves has most effect on growth of the lower portions of the tree.

Because of lighter rust infection on upper leaves, height growth was only slightly reduced during the first year, although apparently rust infection did influence height because trees sprayed with fungicide were slightly taller than unprotected trees. In all three clones at each location, the percentage increase in basal diameter was greater in sprayed than unsprayed trees, and most increases were significantly greater. Basal diameter growth was more severely affected because the lower leaves, which contribute most to basal growth, were most severely infected with rust. Basal diameter growth was reduced 23 percent by rust in NC 5377 at Rhinelander. A 23-percent reduction in diameter growth with no decrease in height growth means that the volume of wood produced was reduced by about 41 percent. If the fungicide used to protect trees from rust had been more effective, protected trees might well have grown even larger than unprotected trees.

The rust severity on protected and unprotected trees of each clone was well correlated with the number of leaves remaining on those trees late in the growing season. Because leaf abscission will occur when at least 50 percent of a leaf surface is covered with uredial pustules (Filer 1975), many of the lower leaves of severely rusted trees will be lost before normal defoliation in the fall. Clone NC 5339 was not affected by the rust at either location, so number of leaves per stem was identical for both protected and unprotected trees. At Rosemount, trees of clone NC 5377 became only lightly rusted. Height in both protected and unprotected plots was about the same. Basal stem diameter of unprotected trees was slightly less than protected trees. At Rhinelander, rust was much more severe on unprotected trees than on protected trees, and the effect of the rust is reflected in leaf loss, reduced height growth, and reduced basal stem diameter of unprotected trees. The impact on basal stem diameter of leaf rust is particularly evident for clone NC 5377 at Rhinelander. Clone NC 5261 is so susceptible to leaf rust that the fungicide used was ineffective in preventing severe rust on sprayed trees. However, fungicide protection did delay defoliation, and at Rosemount, the delayed defoliation contributed to both increased height and basal stem diameter growth.

Of particular interest is that although unprotected trees of the moderately resistant clone NC 5377 were only lightly to moderately rusted, the infection significantly slowed basal diameter growth and thereby volume growth. NC 5261 grew more slowly after July than before, although the other clones grew more rapidly between July and September. At both Rhinelander and Rosemount, trees of this clone set a terminal bud in August. However, protected trees usually set the terminal bud later than unprotected trees, and the lack of accelerated growth during August and early terminal bud set at both Rosemount and Rhinelander are probably due more to leaf rust than to a genetic pecularity of that clone.

Therefore, it is evident that poplar leaf rust does have a significant impact on the growth of infected poplars and that the growth loss may be more severe than previously suspected. Clone NC 5377 at Rosemount was rusted to an RSR of only slightly above the cutoff limit set by Schreiner (1959), but suffered a growth loss of more than 20 percent. Perhaps poplars planted within the geographic range of *L. laricina* should be even more resistant to leaf rust than previously suspected.

Because poplars at Rhinelander growing close to larch became severely infected more than 1 month earlier than poplars growing south of the natural range of eastern larch, plantations of poplars should not be established close to natural or planted stands of larch or hemlock (*Tsuga canadensis* (L.) Carr.). Isolates of *M. medusae* hybridize on eastern larch and *M. abietis-canadensis* on eastern hemlock, and therefore planting resistant poplars close to the alternate host can lead to development of rust that can become severe on previously resistant poplars. Ultimately, increased poplar plantation

acreage close to alternate hosts may increase the rust hazard to poplars planted outside of the range of the alternate host.

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HYBRID POPLAR DISEASES AND DISEASE RESISTANCE

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Three foliage diseases and one canker disease were found on hybrid poplars in clone nurseries at Ames, Iowa, and Rhinelander, Wisconsin, during the 1975 growing season. Marssonina brunnea *and* Septoria *sp. were the most serious foliage diseases at Ames, while* Melampsora medusae *leaf rust infection was serious on only a few of the clones. One clone was lightly infected and six were heavily infected by an as yet unidentified canker disease. At Rhinelander,* Marssonina *and* Septoria *were present but not serious;* Melampsora *leaf rust was serious on a number of clones. The resistance of the clones to diseases is compared and recommendations are made for selecting clones to minimize foliage and canker disease.*

Research on species and hybrids of poplars is underway to select clones and culture techniques most suitable for maximum wood fiber production from plantations in the north-central United States. One way to produce maximum wood fiber is to reduce tree disease to a minimum.

In Europe, where poplars have been grown in plantations for many years, several diseases are important. Among these are *Dothichiza populea* Sacc. and Briard canker (Schönhar 1960), *Marssonina brunnea* (El. & Ev.) Magn. leaf blight (Gremmen 1965), *Melampsora* spp. leaf rusts (Meider 1958), and *Pollacia radiosa* (Lib.) Bald & Clif. shoot blight (Weisgerber 1968). In the United States, poplar plantation research in the East and South has shown that *Melampsora medusae* Thüm leaf rust (Schreiner 1959), and *Septoria musiva* Peck leaf spot and canker (Filer 1975, Waterman 1954) can damage young trees. Much less research on diseases of poplars in plantations has been done in the north-central United States, although *M. medusae* has been found to be important in plantings in Wisconsin (Dawson 1974, Schipper and Dawson 1974).

Tree disease can reduce growth and kill trees in plantations, so we need to know which diseases will be important to poplar plantations in the north-central States and how best to control those diseases. Toward this end, poplar clone nurseries in Iowa and Wisconsin were examined for disease problems and clonal resistance to the diseases studied.

METHODS

Two hybrid poplar clone nurseries established in 1971 were examined in July and September of 1975. One of the nurseries was located on the Iowa State University experimental farm at Ames, Iowa (lat. 42° 0' 45", long. 93° 38' 10"), and the other on the Hugo Sauer State Tree Nursery at Rhinelander, Wisconsin (lat. 45° 39' 3", long. 89° 29' 5"). The same clones had been planted at each nursery. A survey was made at each location to determine which foliage and stem diseases were present and important. Subsequently, each tree of each of 35 clones was examined and the severity of the individual foliage and stem diseases present was rated by the method developed by Schreiner (1959). The amount of leaf rust or other foliage disease is rated as light, medium, or heavy and given numerical values of 1, 5, or 25, respectively. The percent of total leaves infected is then rated as less than 25 percent,

26 to 50 percent, 51 to 75 percent, or greater than 75 percent, with a numerical rating of 1, 2, 3, or 4, respectively. The product of the two numerical ratings gives a disease severity rating of from 0 (immune) to 100 (highly susceptible). Stem canker severity was determined by counting the number of cankers per main stem of each affected tree in the clone.

RESULTS AND DISCUSSION

At Ames, three foliage diseases and one canker disease were found on hybrid poplar clones (table 1). *Marssonina brunnea* (El. & Ev.) Magn. infection on leaves of hybrid poplar clones was rated as heavy on 12 clones in July and on 14 clones in September (fig. 1). Clones especially susceptible to the disease were NC 4878, NC 5258, NC 5270, NC 5321, NC 5324, NC 5328, and NC 5373. (The NC number is an accession number assigned each clone at the North Central Forest Experiment Station.) Each of the above clones had a disease severity rating of 100 in July; one of them, NC 5270, was about 75 percent defoliated in July (fig. 2) and had only a few remaining leaves in September. The other clones with a severity rating of 100 suffered some defoliation in July and more in September.

Septoria sp. leaf spot (probably *S. musiva* Peck) also was more severe on some cultivars than on others (fig. 3). In July, 12 of 32 cultivars were heavily infected; the same clones were still infected in September, but no additional clones had become heavily infected. Evidently *Septoria* is a disease of the spring and early summer and does not increase in severity during the summer, while *Marssonina* becomes more severe as the growing season progresses. In some cases, both *Marssonina* and *Septoria* were heavy on leaves of the same clone, but in many cases, either one disease or the other was heavy on a clone. Thus, although most clones were moderately to highly resistant to either *Marssonina* or *Septoria*, only eight clones were sufficiently resistant to both diseases to warrant further consideration in a location where both *Marssonina* and *Septoria* are likely to be present.

None of the clones at Ames was even moderately infected by *Melampsora medusae* Thüm leaf rust in July, and only three clones were moderately to severely infected in September.

Heavy cankering was found on clones NC 5263, NC 5264, NC 5266, NC 5268, and NC 5334

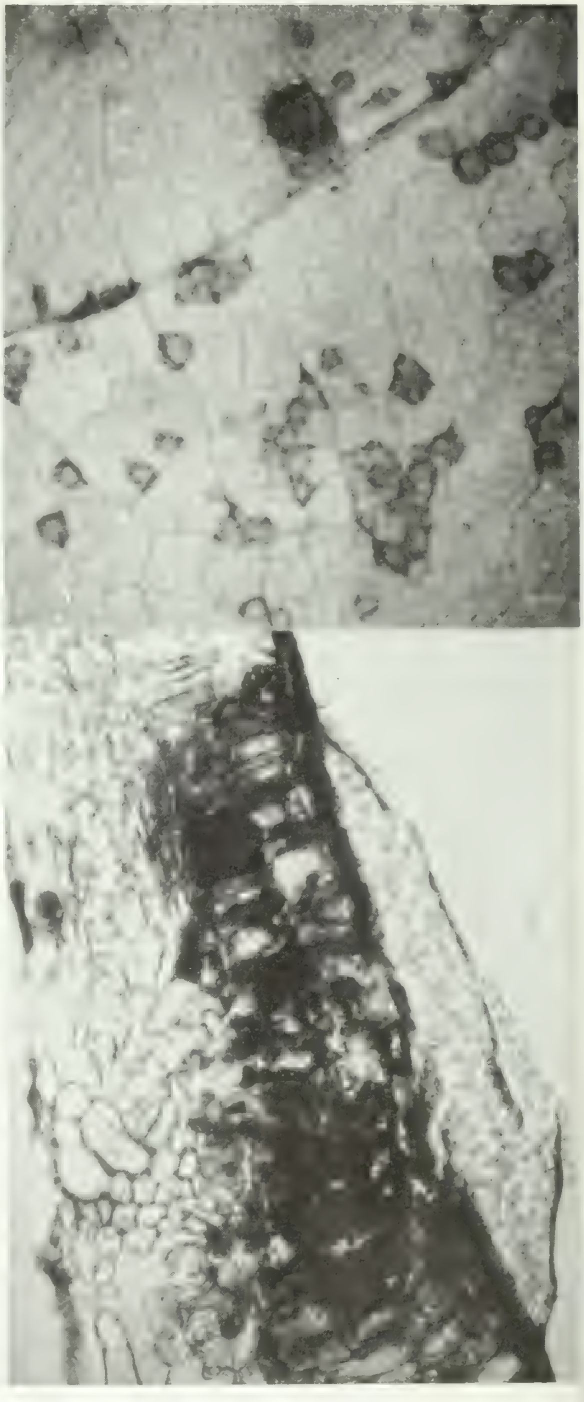

Figure 1.--*Top.* Marssonina brunnea *leaf spot of hybrid poplars. Bottom. Photomicrograp[h] of a hybrid poplar leaf showing* M. brunnea *infection.*

at Ames, while NC 5325 had a few cankers (fig. 4). With the exception of NC 5335, a[ll] these clones also were heavily infected wit[h] *Septoria* leaf spot and the cankers appeared

Table 1.--*Foliage disease severity by species and clone at Ames, Iowa, and Rhinelander, Wisconsin, in 1975*

Cultivar identification number	Parentage and cultivar designation	Foliage disease severity by cultivar in 1975											
		Ames, Iowa						Rhinelander, Wisconsin					
		Marssonina		*Melampsora*		*Septoria*		*Marssonina*		*Melampsora*		*Septoria*	
		7/24	9/24	7/24	9/24	7/24	9/24	7/27	9/9	7/27	9/9	7/27	9/9
4877	*Populus alba* 'PI 343437'	VL[1/]	0	0	0	VL	2	--	--	--	--	--	--
5339	*P. alba* x *P. grandidentata* 'Crandon poplar'	--	--	--	--	--	--	0	0	1	10	0	0
5264	*P. angulata* x *P. platierensis* 'NE 376'	20	20	0	17	100	100	0	0	1	10	0	0
5334	*P. angulata* x *P. trichocarpa* 'NE 258'	12	3	0	7	94	[2/]20	0	0	VL	4	0	0
5265	*P. angulata* x *P. trichocarpa* 'NE 274'	31	77	0	20	89	100	0	0	1	50	0	0
5266	*P. angulata* x *P. trichocarpa* 'NE 372'	60	100	0	20	100	100	0	0	50	50	0	0
5331	*P. berolinensis* x *P. trichocarpa* 'NE 219'	12	40	0	4	59	40	0	0	1	4	0	0
5332	*P. berolinensis* x *P. trichocarpa* 'NE 298'	80	100	0	4	18	12	0	0	2	4	0	0
5262	*P. candicans* x *P. berolinensis* 'NE 387'	9	4	0	4	85	84	0	0	0	4	0	0
5263	*P. candicans* x *P. berolinensis* 'NE 386'	4	3	0	20	90	100	0	0	VL	4	0	0
5271	*P. charkowiensis* x *P. deltoides* 'NE 19'	6	4	0	4	8	4	0	0	0	4	0	0
5318	*P. deltoides* 'D 37'	4	7	0	6	4	4	20	20	2	4	0	0
5319	*P. deltoides* 'D 45'	8	20	0	4	3	4	3	20	10	20	0	20
5273	*P. deltoides* '44-52'	93	100	0	50	10	10	0	20	15	100	0	0
5261	*P. deltoides* x *P. balsamifera* 'Northwest'	5	21	10	100	69	100	0	def[3/]	91	def	0	def
5267	*P. deltoides* x *P. caudina* 'NE 366'	4	4	0	20	83	100	0	0	1	50	0	0
5268	*P. deltoides* x *P. trichocarpa* 'NE 216'	20	20	0	15	100	100	0	0	5	50	0	C
5335	*P. deltoides* x *P. trichocarpa* 'NE 348'	52	52	0	12	78	100	0	0	5	50	0	0
5270	*P. deltoides* x *P. trichocarpa* 'NE 205'	100	[4/]100	0	17	20	20	0	0	25	100	0	0
4878	*P.* x *euramericana* 'PI 343438'	20	20	0	14	4	4	0	0	4	20	0	0
4879	*P.* x *euramericana* 'PI 343439'	100	100	0	8	3	4	0	0	3	75	0	0
5321	*P.* x *euramericana* 'Negrito de Granada'	100	100	0	7	3	3	0	0	50	75	0	0
5322	*P.* x *euramericana* 'Jaconetti 78B'	73	100	0	17	4	4	4	0	50	50	0	20
5323	*P.* x *euramericana* 'Canada Blanc'	20	22	0	20	3	6	10	20	10	35	0	10
5324	*P.* x *euramericana* 'DN 26'	100	100	0	31	3	4	0	0	20	20	0	0
5325	*P.* x *euramericana* 'Ostia'	19	13	0	20	3	4	0	0	25	100	0	0
5326	*P.* x *euramericana* 'Eugenii'	60	50	0	0	VL	11	0	0	1	20	0	0
5327	*P.* x *euramericana* 'I 214'	18	20	0	9	3	4	--	--	--	--	--	--
5328	*P.* x *euramericana* 'Guinier'	100	100	0	6	4	5	0	0	20	20	0	0
5377	*P.* x *euramericana* 'Wisconsin #5'	20	50	0	4	VL	4	0	0	1	20	0	0
5272	*P. nigra* x *P. laurifolia* 'NE 1'	VL	7	0	0	95	20	0	0	0	1	0	0
5260	*P. tristis* x *P. balsamifera* 'Tristis #1'	8	21	0	21	VL	7	0	0	2	4	0	0
5258	*Populus* sp.	100	100	0	.4	VL	4	0	0	2	4	2	10
5351	*Populus* sp.	--	--	--	--	--	--	0	0	40	100	0	0
5253	*Populus* sp.	--	--	--	--	--	--	4	20	15	20	0	0

1/ VL = very light infection; i.e., 1 to 10 pustules per leaf.

2/ A decrease in disease severity at September readings indicates defoliation of leaves heavily infected in July. Readings in September were made from remaining leaves.

3/ def = defoliated before reading made.

4/ NC 5270 was 75 percent defoliated in July. By September, only a few leaves per tree remained. Readings were made from the remaining leaves.

similar to *Septoria* canker (Filer 1975, Waterman 1954). However, isolations from these cankers have yielded *Alternaria* sp., *Fusarium* sp., and *Septoria* sp. Inoculation studies are not complete, so a pathogen cannot yet be linked to these cankers. All of the cankers were within 1.5 m of the ground and appeared to be centered around a lenticil.

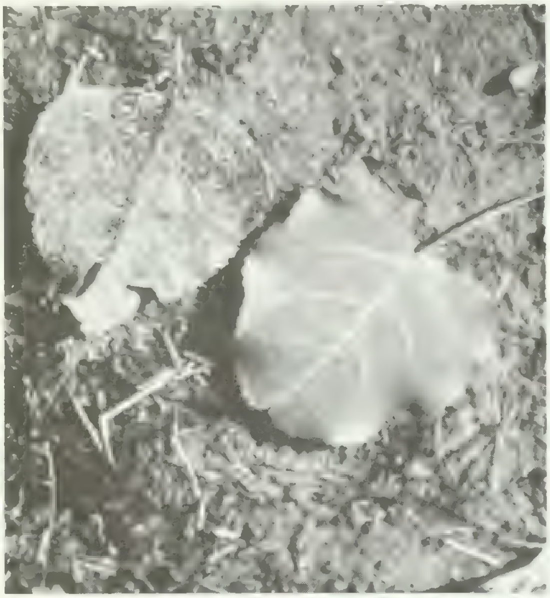

Figure 2.--*Severe infection of* Marssonina-*susceptible clone NC 5270 (*P. deltoides *x* P. trichocarpa*) on left compared with* Marssonina-*resistant clone NC 5318 (*P. deltoides*) on the right. The two trees were adjacent.*

Figure 3.--*Top.* Septoria *sp. leaf spot of hybrid poplar. Note the typical dark border and light center of the leaf spot and the dark pycnidia in the center of the spot. Bottom. Photomicrograph of a* Septoria *pycnidia showing the spores.*

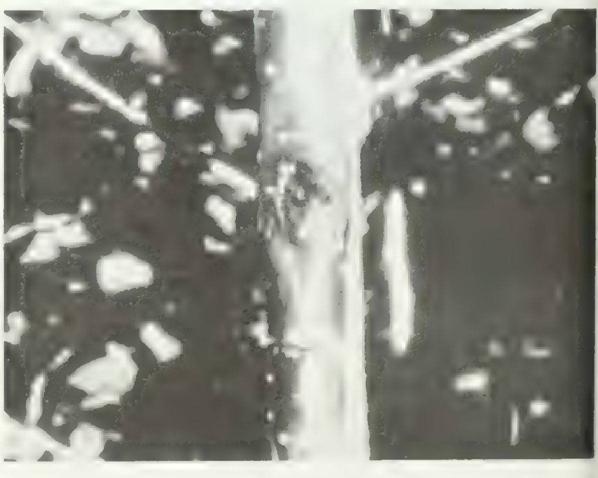

Figure 4.--*Canker of hybrid poplar at Ames.*

Some of the main stems of these clones had as many as 20 cankers in the lower 1.5 m.

At Rhinelander, only *Melampsora* leaf rust was found to be a serious problem (table 1). Although *Marssonina* and *Septoria* were present, none of the clones was more than lightly infected with either disease. In contrast, several clones (notably NC 5261, NC 5266, NC 5321, and NC 5322) were heavily rusted by the end of June. Other clones were only lightly infected with rust in July but by early September were heavily infected. Of the 33 clones rated for leaf rust severity at Rhinelander, 14 would be disqualified from further consideration as plantation planting stock if disease impact were the sole criterion for selection. *Melampsora* infection was lighter at Ames than at Rhinelander because at Rhinelander, infection starts in early June from spores produced on nearby larch (*Larix laricina* (Du Roi) K. Koch), while at Ames, infection begins in August from windblown uredospores from the north, and infection does not become heavy until September.

The nurseries examined at Ames and Rhinelander each contained 30 of the same hybrid poplar clones. In addition, the nursery at

Ames had two clones not planted at Rhinelander and the one at Rhinelander had three clones not planted at Ames. The clones, obtained from various tree breeding sources, represented 14 species and hybrids of *Populus*. Because six of the species and hybrids were represented by two or more clones, comparing their resistance to three foliage diseases and one canker disease was possible. Although the sample population is too small to draw general conclusions about the suitability of various hybrids, a wide diversity of resistance and susceptibility was found and several interesting differences in resistance within hybrids observed. For instance, at Ames, one of the three clones of the hybrid *P. angulata* x *P. trichocarpa*, NC 5334, was resistant to *Marssonina*, while the other two were susceptible. However, all three clones were susceptible to *Septoria* leaf spot, and NC 5334 was severely defoliated by *Septoria* infection. At Rhinelander, NC 5334 was rust resistant, NC 5265 exhibited early season resistance but late season susceptibility to rust, and NC 5266 was susceptible to rust throughout the season.

P. berolinensis x *P. trichocarpa* was represented by two clones. NC 5331 exhibited midseason resistance to *Marssonina*, although it was moderately infected in late September. NC 5332 was heavily infected with *Marssonina* in July. However, resistance to *Septoria* was exactly reversed: NC 5331 was susceptible and NC 5532 was moderately resistant. Both clones were resistant to rust at Rhinelander.

P. berolinensis x *P. candicans* was also represented by two clones. Both were resistant to *Marssonina* at Ames and both were very susceptible to *Septoria*. At both locations, these clones were rust resistant.

Three clones of *P. deltoides* were planted at each location. NC 5318 and NC 5319 were resistant to all three diseases at both locations, while NC 5273 was resistant to *Septoria* but susceptible to *Marssonina* and *Melampsora*.

For three clones of *P. deltoides* x *P. trichocarpa*, NC 5268 was resistant to *Marssonina* but susceptible to *Septoria*, NC 5335 was susceptible to both diseases, and NC 5270 was resistant to *Septoria* but was the clone most susceptible to *Marssonina* of those examined at Ames. All three clones were susceptible to *Melampsora* at Rhinelander but were rated as resistant at Ames. This apparent resistance was because rust at Ames develops much later than at Rhinelander (see Widin and Schipper article on p. 63) and apparently only becomes heavy on extremely susceptible clones when planted far enough south to avoid early season infection.

P. x *euramericana* was represented by 11 clones. All of these clones were resistant to *Septoria* infection, but seven were susceptible to *Marssonina*. At Ames, only clone NC 5324 was moderately susceptible to *Melampsora*, while at Rhinelander, five of the clones were moderately to highly susceptible to *Melampsora*.

Seven other clones were planted at both Ames and Rhinelander. However, because each represented a single hybrid, no information is available about resistance or susceptibility within the hybrid. Of these clones, NC 5271 was highly resistant to the three diseases at both locations.

Four additional clones were planted at either Ames or Rhinelander. Of these, NC 4878 and NC 5339 were highly resistant to the three diseases and probably would perform satisfactorily at both locations.

Some of the clones checked are suitable for planting at one location but not at the other. For instance, NC 4877,[1/] NC 5323, and NC 5327 could be planted at Ames but would be heavily infected by *Melampsora* leaf rust at Rhinelander. Thirteen clones (NC 5253,[1/] NC 5258, NC 5262, NC 5263, NC 5264, NC 5272, NC 5326, NC 5328, NC 5331, NC 5332, NC 5334, NC 5339,[1/] and NC 5377) could be planted at Rhinelander but would be too susceptible to *Marssonina* or *Septoria* to be planted at Ames. Only five clones, NC 4878, NC 5260, NC 5271, NC 5318, and NC 5319, could be planted at both locations without fear of growth loss due to the diseases prevalent at Ames and Rhinelander during 1975. Clones NC 4877 and NC 5339 probably could be added to this list but were not planted at both locations.

Because the diseases encountered in hybrid poplar clone nurseries in Iowa and Wisconsin were so different, it appears likely that the diseases encountered by hybrid poplar clones in the north-central United States will vary at least from north to south, if not by location, within the region. Therefore, clones must be rated for resistance to the prevalent diseases in each geographical region before large plantings of hybrid poplars are made. Clone nurseries such as those at

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1/ See table 1 for details of disease infection of these clones.

Ames and Rhinelander seem ideal for assessing diseases likely to be locally important on hybrid poplars and for screening clones for resistance or susceptibility to the important diseases.

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POPLAR PLANTATION DENSITY INFLUENCES FOLIAGE DISEASE

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Melampsora *leaf rust was more severe in hybrid poplar plots planted to high densities than in plots of the same clones at low densities. A compromise between high density to maximize wood production and low density to reduce disease must be reached in plantation density recommendations.*

Stand density, the number of trees per hectare (ha), is important in forest plantation establishment. Within certain limits, more trees per ha mean more product per ha. Density also influences tree form, self-pruning, root crowding, and use of soil by the plants. As trees are planted closer, lower branches tend to die and self-prune earlier. Because of the desire to produce the most product per ha, high stand density is often a goal of forestry research.

However, the higher the density, the more favorable becomes the environment for foliage diseases. As density increases, air movement through the foliage decreases and moisture evaporates from the leaves more slowly. Because most foliage pathogens require free moisture on leaves for spore germination and infection, slower moisture evaporation tends to increase infection.

To determine the influence of density on hybrid poplar growth, and ultimately to establish density recommendations for poplar plantation establishment in the north-central region experimental plantings were established at Ames, Iowa, and Rhinelander, Wisconsin. In one experiment set up by the Iowa State University, Department of Forestry, and duplicated at Ames and Rhinelander, 4 hybrid poplar clones were planted at densities of 15,000 stems/ha (0.8 m between trees), 10,000 stems/ha (1.0 m between trees), and 5,000 stems/ha (1.4 m between trees).

In September of 1975, I examined the plantations at Ames and Rhinelander to determine what influence these three stocking densities had on the severity of *Melampsora* leaf rust. This rust, caused by the fungus *Melampsora medusae* Thüm, is the predominant hybrid poplar disease at Rhinelander plantings (Schipper and Dawson 1974, see article by Schipper on p. 75).

METHODS

The hybrid poplar clones planted in the experimental plots were NC 5321 (*Populus* X *euramericana* 'Negrito de Granada'), NC 5323 (*P.* X *euramericana* 'Canada blanc'), NC 5326 (*P.* X *euramericana* 'Eugenii'), and NC 5377 (*P.* X *euramericana* 'Wisconsin No.5'). These clones were selected because of growth and wood characteristics. When rated for leaf rust resistance in 1971 and 1972 (Dawson

1974) each was considered to be moderately to highly resistant.

Each spacing plot at Ames and Rhinelander contained 49 trees of only 1 clone, planted in a square and surrounded by 2 border rows at the same spacing. In order to avoid edge effects as much as possible in such small plots, only the 10 center-most trees in each plot were rated for rust.

Trees were rated for leaf rust by the method developed by Schreiner (1959). In this method, the plant is scored as lightly, moderately, or heavily infected and given a numerical rating of 1, 5, or 25, respectively. Then the percent of leaves per tree infected with rust is estimated and given a numerical rating as follows: less than 25 percent = 1, 25 to 50 percent = 2, 51 to 75 percent = 3, and greater than 75 percent = 4. The numerical rating of leaf infection is multiplied by the numerical rating derived from percent of each tree infected to give an estimate of tree infection ranging from 0 (immune) to 100 (very highly susceptible). In order to avoid bias in estimating leaf infection and percent of tree infected, I rated each leaf on each tree as uninfected, lightly, moderately, or heavily infected and averaged the leaf ratings per tree. The percent of tree infected also was determined from these data and multiplied by average leaf rating to arrive at a rust severity rating for each clone at each planting density.

RESULTS

Rhinelander Plots

At the widest tree spacing (low density), NC 5326 and NC 5377 had a rust severity rating (RSR) of less than RSR 25 and both cultivars retained the low rating at the intermediate spacing (fig. 1). At the narrow spacing (high density), however, both cultivars had rust severity ratings of almost 50. Schreiner (1959) stated that for ratings made late in the growing season, cultivars rated at RSR 25 or greater "should not be recommended for planting in the localities where such tests have been carried on." Thus at the low and intermediate stocking density, both NC 5326 and NC 5377 exhibited sufficient resistance to leaf rust to be considered for planting stock. However, at the highest density, neither cultivar could be recommended.

NC 5321 and NC 5323 both had a rust severity rating of about 35 at the widest

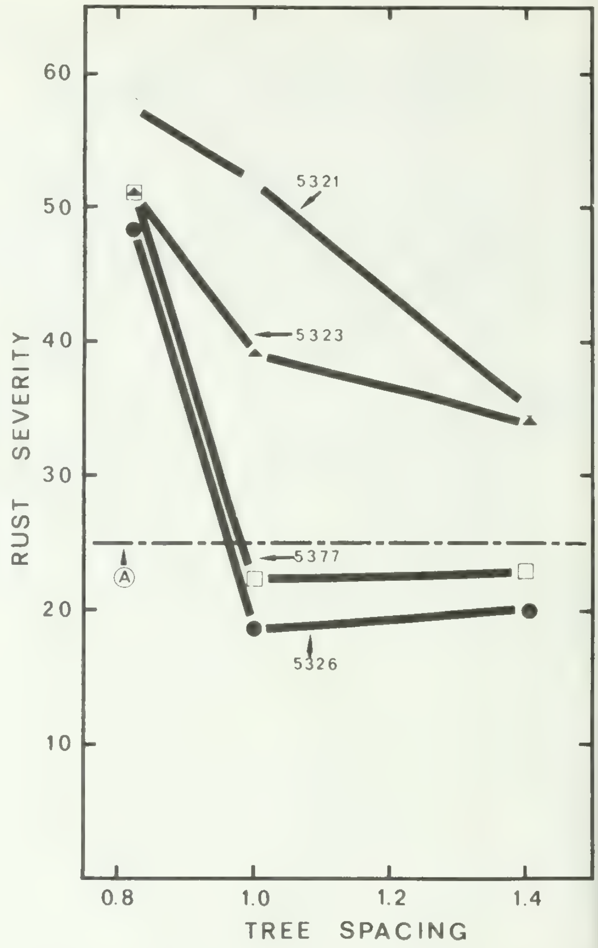

Figure 1.--*Rust severity on leaves of four poplar clones in relation to tree spacing. At a tree spacing of 0.8 m, 15,000 stems/h can be planted, at 1.0 m, 10,000 stems/ha, and at 1.4 m, 5,000 stems/ha. The dashed line at A is the arbitrary limit for rust susceptibility set by Schreiner. Cultivar more heavily rusted than RSR 25 should be excluded from selection programs. Because spacing affects rust severity, poplars should not be rated for resistance when planted at unusually close spacings.*

spacing, and exhibited an almost direct relation between density and rust severity. If wider spacings had been tested, these clones also would have reached a rust severity rating no longer influenced by density. Presumably the lower limit of rust severity for these cultivars also would have been below RSR 25. However, at the spacings used in this study, neither clone could be considered sufficiently resistant to warrant further consideration as planting stock.

Ames Plots

Data from density plots at Ames showed a similar relation between stocking and rust severity, although rust was less severe. Incidence of *Marssonina brunnea* (El. & Ev.) Magn. was also scored in these plots, with similar results. *Marssonina* leaf spot of poplars is a potentially serious foliage disease that can cause premature defoliation of susceptible poplars (see article by Schipper on p. 75).

DISCUSSION

Some of the reasons for altered rust severity with different planting density involve the changing space between adjacent tree crowns (fig. 2). At establishment, the plants are widely spaced. As they grow and branches develop, the crowns occupy increasingly large areas and the edges of the crowns become closer together until at the highest stocking density the crowns are merged. When crowns merge, as shown for the highest stocking density at 3 years, little air movement through the foliage occurs and leaves remain wet for longer time periods after rain, dew, or irrigation. Under such conditions of prolonged free moisture, foliage pathogens are best able to infect leaves. Thus, even though the actual resistance of the clones is not altered, trees at narrow spacings are exposed to conditions suitable for infection for longer periods than trees at wider spacings.

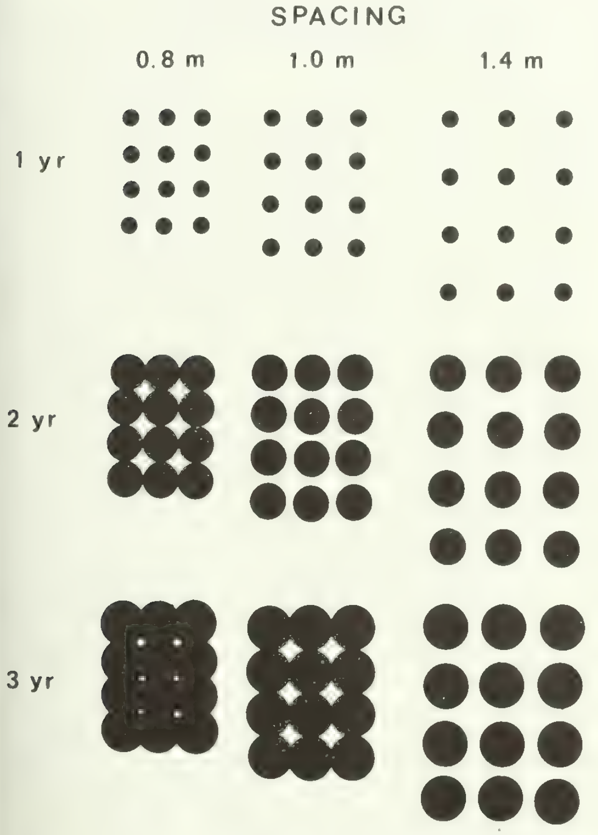

Figure 2.--*Relation between stocking density and crown closure over a 3 year period.*

These data have implications beyond the mere fact that trees planted closely together can become more heavily infected with foliage pathogens than at wider spacings. First, Widin and Schipper (see article on p. 63) have shown that leaf rust can reduce hybrid poplar height and diameter growth compared to protected plants of the same cultivar, when infection occurs early enough in the season. It is reasonable to assume that the impact on tree growth is related to the severity of leaf rust, and to date at which rust begins in the spring. Thus planting hybrid poplars at closer spacings, which will increase rust severity, will cause greater growth loss. In addition, growth data from density experiments where the trees were not protected from disease must be carefully considered before they are used to make stand density recommendations. At narrow spacings tree growth will be reduced because of rust attack, while at wider spacings growth will be closer to that realized with protected hybrid poplars under optimum conditions.

Even if growth data from density plots indicate that close spacing yields more harvestable dry matter, the effect of rust on health in general must be considered. Hybrid poplars heavily infected with leaf rust will be more susceptible to other diseases that affect trees under stress, such as canker diseases. For example, hybrid poplars in Europe infected with *Melampsora larici-populina* leaf rust are more susceptible to *Dothichiza populea* canker (Meiden and Vloten 1958). Also, rust-infected trees have been found to be more susceptible to frost damage (Kessler 1970), and will enter dormancy with less stored reserve than less severely infected trees.

A WORD OF CAUTION

In establishing density recommendations for hybrid poplars, we must consider its effect upon plant health. Foliage diseases will be minimized, to a point, by decreased stocking density while dry matter production will be maximized, to a point, by increased stocking density. Therefore, a compromise between plant health and production will have to be reached. In general, if stocking density is low enough so that crown closure does not occur until the 3rd or 4th year, the hybrid poplars will have been given the best opportunity to establish sound root systems and to adapt to the plantation conditions. After crown closure, the upper crowns of the trees will still be more widely dispersed so that rust and other foliage diseases in these portions of the tree will be minimized.

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DETECTION AND ELIMINATION OF VIRUSES IN POPLARS

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There is a need to identify and to characterize all the viruses that may infect poplars and to develop efficient indexing procedures for detecting them. A tissue culture method already is available for eliminating viruses from poplar clones, so developing a certification program for producing and distributing virus-free poplar stock depends largely upon the development of methods for detecting virus infections. Significant clonal deterioration is not likely to occur in short-rotation plantings of poplars started with disease-free stock.

In the north-central States, the intensive culture of certain species and hybrids of poplars presents the greatest opportunity to achieve maximum wood fiber production, provided that adequate provision can be made for control of the many insects and diseases that may attack them. The fact that poplar wood constitutes the most important component of the industrial wood supply within the region (Spencer and Thorne 1972) also makes the poplars attractive candidates. Further, more than a century of experience in many European countries has established the biological feasibility of intensive poplar culture (FAO 1958, Schreiner 1959).

The inevitable trend toward monoculture in such a program increases the vulnerability of the cropping system to insects and diseases. The greatest potential for insidious disaster due to virus diseases is with monocultures of vegetatively propagated perennial crops. In the long term, monocultures of natural quaking aspen (*Populus tremuloides* Michx.) propagated generation after generation from root sprouts may be as vulnerable to infectious degenerative problems as intensively managed black (Aigeiros) and balsam (Tacamahaca) poplar clones propagated by stem cuttings.

Although catastrophic losses due to insects and diseases have occurred in monocultures of intensively managed agricultural crops as well as unmanaged forests, technology can be developed and applied in an intensive management system to reduce greatly the possibility of such occurrences. Ways of dealing with potential insect and fungal disease problems are dealt with elsewhere. The purpose of this paper is to examine the possible significance of virus diseases in the intensive culture of poplars and to discuss tissue culture methods for the elimination of viruses from infected poplar clones.

NATURE, SIGNIFICANCE, AND CONTROL OF INFECTIOUS DEGENERATIVE DISEASES OF CLONAL CROPS

Virtually all vegetatively propagated agricultural and ornamental crops of the world have been exposed to infectious, degenerative diseases that have threatened the continuity of their economic production (Hollings 1965). A flourishing international trade and the prevalence of monoculture

promise to make matters worse. Without disease control, many of the affected crops could not be maintained, except in certain regions.

In many examples of progressive degenerative problems in vegetatively propagated crops, single or multiple persistent infections by viruses have been found responsible. These disorders have been referred to by many names such as quick decline, slow decline, running-out disease, dieback, little leaf, yellows, and degeneration. In some plants, infections by systemic pathogens, including viruses, may increase in severity during succeeding generations and result in a gradual increase of the degeneration problem (Brierley and Lorentz 1957, Cadman 1952, Olson 1959). This kind of problem rarely results in the death of the affected plants; the major effect being a drastic reduction in growth and yield (Cadman 1952, Chambers 1961, Krietlow *et al.* 1957).

There are presently no practical methods to cure virus-infected plants once they are set out in the field. The production and distribution of virus-free propagating stock is the most practical method of controlling virus diseases of many crops. A more advanced technology will allow for its application to a wider array of agricultural crops, including forest trees.

Control through the use of virus-free stock aims to curtail disease spread by the dilution of infective plants with healthy, virus-free planting stock. To realize this objective, techniques for eliminating viruses from plants first must be developed. Present techniques include (1) exploiting erratic virus distribution in the plant, (2) meristem-tip culture, (3) chemotherapy, (4) thermotherapy (Hollings 1965), and (5) tissue culture (Abo El-Nil 1974, Omuemu 1975, Sushak 1975).

Some viruses occur erratically throughout the plant; thus, isolation and propagation of small pieces of plant tissue may yield virus-free clones. For example, many gladiolus cormels removed from virus-infected mother corms proved free of cucumber mosaic virus (Brierley 1963).

Morel and Martin (1955) obtained virus-free dahlia and potato plants by propagating plants directly from small pieces of tissue cut from the growing tips of virus-infected plants. This technique, termed meristem-tip culture, currently is being used to produce and maintain virus-free stocks of many agricultural crops (Hollings 1965, Holmes 1968).

Claims of the cure of virus-infected plants by the use of chemical therapeutants, such as cytovirin, have been made, but none has been confirmed. The only present practical use of antiviral chemicals may be to supplement the effectiveness of meristem-tip culture.

Heat treatment is the most successful and widely used therapeutic method, especially when used to augment meristem-tip culture (Brierley 1957, Campbell 1962). Many of the viruses infecting horticultural plants might be eliminated by heat treatment (Kassanis 1957). Heat treatment inhibits the spread of certain viruses into apical growing tips of plants; tip-cuttings then taken and propagated are likely to produce virus-free plants (Hollings 1965, Nyland and Goheen 1969).

For several clonal crops, tissue culture has proven the most effective method for eliminating systemic pathogens. In this paper, the term tissue culture is defined as the aseptic technique involving the production of callus from apical shoot tips (0.5 to 1.0 mm long) and the differentiation of plantlets from the callus. The other methods described above are likely to eliminate some, but not all, of the pathogens. For example, in our work with diseased cassava clones, heat therapy consistently eliminated the mosaic disease agent, but not the leaf curl disease agent; meristem-tip culture eliminated both agents from about 50 percent of the cultured material, but tissue culture eliminated both disease agents from 100 percent of the cultured material (Omuemu 1975). Tissue culture has consistently eliminated tobacco ringspot virus from geraniums (Abo El-Nil 1974) and all apparent virus infections from gladiolus (Sushak 1975); other methods have not. Elimination of disease agents from geranium and cassava clones by tissue culture resulted in dramatic increases in the vigor and growth rates of the plants (Abo El-Nil 1974, Omuemu 1975).

DETERIORATION OF POPLAR CLONES

From about 1937 to 1954, Emeritus Professor A. J. Riker and associates, especially J. E. Kuntz, accumulated at the University of Wisconsin one of the world's

largest collections of poplar species and hybrids. The collection included more than 1,000 clones of black (Aigeiros) and balsam (Tacamahaca) poplar species and hybrids.

These clones were evaluated in small replicated plots. Most of them proved unsuitable for use in Wisconsin for a variety of reasons and were discarded. Approximately 0.1 percent of them appeared promising. They had at least field resistance to the then known poplar diseases of economic significance and were selected for resistance to attack by the poplar-and-willow borer, *Cryptorhynchus lapathi* (L.). They grew rapidly, and a representative clone produced a wood comparable in quality to that of the quaking aspen (Laundrie and Berbee 1972).

These highly selected clones have been observed through two and a half 12-year or longer rotations. Near the end of the first rotation, a decline and dieback problem of unknown origin began to appear. The severity of this decline problem seemed to increase with succeeding generations. By 1970, it was evident in the nursery that randomly selected, open-pollinated eastern cottonwood seedlings were outperforming our most highly selected Aigeiros poplar clones. Cooper and Randall (1973) of the USDA Southern Forest Experiment Station reported somewhat similar results comparing their highly selected eastern cottonwood clones with full-sib families of eastern cottonwood seedlings. The families of seedlings performed better than the clones.

Only one Aigeiros clone in the entire Wisconsin collection of poplars has not deteriorated. This female clone, NE 244, was sent to us by the USDA Northeastern Forest Experiment Station as an intraspecific hybrid between *P. deltoides angulata* and *P. deltoides virginiana*. Unfortunately, this rapidly growing, decline-resistant clone proved susceptible in Wisconsin to winter injury, resulting in stem basal damage on the southwest side of the trees. Although somewhat more difficult to root from stem cuttings than many other poplar clones, NE 244 should be a candidate for intensive culture within the southern range of *P. deltoides*.

Clonal deterioration also has occurred in monocultures of quaking aspen naturally regenerated from root sprouts, both in the eastern and western United States (Schier 1975). Schier presented a plausible physiological explanation for the deterioration of aspen clones, but acknowledged that deterioration might be caused by viruses.

VIRUS DISEASES OF POPLARS

The only poplar virus that has been thoroughly studied is poplar mosaic virus. This rod-shaped virus (Brčák and Blattný 1962, Navratil and Boyer 1970) is widespread in Europe, causes growth reductions in nursery stock, and reduces the specific gravity of poplar wood (Biddle and Tinsley 1971a, 1971b). It has been reported in Canada (Navratil and Boyer 1970), but has not yet been found in the United States. A widespread, aphid-transmitted, leaf-spotting disease of aspen species and hybrids in Canada described by Boyer (1962) may be caused by a virus (Boyer and Navratil 1970). This disease is very likely present and widespread in the United States.

Our efforts to detect viruses in Aigeiros and quaking aspen clones exhibiting decline symptoms have resulted in the isolation of an apparently new poplar virus. It has been recovered from five different Aigeiros clones. The herbaceous host range of this virus, symptoms it produced in several susceptible host plants, and its morphology as revealed by electron microscopy distinguished the new virus isolate from poplar mosaic virus. It is a flexuous rod with an average length of 750 nm. Purified preparations of the virus proved infectious. It belongs to the potato virus Y group. A virus isolate recovered consistently from a deteriorating quaking aspen clone may be identical to isolates recovered from Aigeiros poplar clones.

Additional work is needed to develop efficient methods for detecting this virus in poplars, to determine its effect on growth rate, and to determine its role, if any, in the deterioration of poplar clones.

TISSUE CULTURE OF AIGEIROS POPLARS

Methods for producing sterile poplar callus in culture and for producing plants from it have been developed (Berbee *et al.* 1972, Winton 1970). However, the method to do this must be determined for each different poplar clone to be cultured.

Three different sequences of three culture media have been required to tissue culture various poplar clones.

To date, 7 different Aigeiros poplar clones have been tissue cultured to produce more than 200 different subclones. During this process, the original parent clones were rejuvenated, as was evidenced by an ontogeny of tissue-cultured plantlets similar to that of seedlings. The tissue-cultured subclones were all virus symptomless, but efficient indexing procedures remain to be developed to establish them virus free.

The growth performances and forms of 162 different subclones derived from 5 different *P.* x *euramericana* parent clones and from a clone of *P. nigra* L. cv. 'italica' were compared at Wilson State Nursery, Boscobel, Wisconsin. There was no significant difference between the performance of subclones derived by tissue culture before thermotherapy and of those derived after thermotherapy (36°C, 3 to 12 weeks) from a given parent clone. There were significant variations in the growth rates and in the branching habits not only among the subclones derived from any one parent clone, but even among the clones derived from individual callus cultures. This unexpected result provided an opportunity to select subclones with various desired combinations of characteristics and possibly to increase the biological efficiencies of poplar clones. However, approximately 10 percent of the tissue-cultured subclones exhibited conspicuous genetic damage.

The variation among subclones of single origins could be due to total elimination of systemic pathogens from some of the subclones and elimination of only some variable proportion of them in others. The success of tissue culture in eliminating all pathogens from several other crops negates this explanation, however. A still unknown genetic basis for the phenomenon seems more likely.

DISCUSSION

Experience with the intensive culture of vegetatively propagated agricultural and ornamental crops suggests that viruses cause gradual deterioration of clonal plant materials, including poplars, unless appropriate measures are developed and applied to avoid it. The problem develops in plant clonal material because (1) plants do not have immune systems comparable to those of animals that destroy invading pathogens and, thus, once a plant becomes infected with a virus, it usually remains infected for life; (2) plants may become systemically infected with any number of unrelated viruses that cumulatively may increase both the rate and ultimate severity of the deterioration of the affected clone; and (3) accumulating virus infections are carried through succeeding crop generations by vegetative propagation, but relatively infrequently through seed.

Requirements for minimizing the risk of clonal deterioration in intensive poplar culture include (1) indentifying the viruses that may infect poplars and development of efficient indexing procedures for their detection; (2) determining the alternate natural hosts and the modes of transmission of poplar viruses as a basis for formulating measures to minimize their spread; (3) developing and applying methods for eliminating viruses from infected poplar clones; and (4) organizing a program for maintaining and distributing disease-free planting stock of clonal purity.

The detection, isolation, and partial characterization of an apparently new virus associated with deteriorating poplar clones are essential first steps in our investigation of poplar viruses. However, this phase of our work still is at an early stage. There is no conclusive evidence that this virus contributes to the deterioration of poplar clones. An efficient indexing procedure for detecting it in poplars is needed. Its natural hosts and mode of transmission and the effects of the virus on the growth and performance of different poplar clones remain to be determined. In addition other viruses probably will be found infecting poplars and each of these will require study.

A method for eliminating systemic pathogens, including viruses, from infected Aigeiros poplar clones is available (Berbee *et al.* 1972). In dealing with poplars that may be infected with many presently undetected viruses, tissue culture involving the differentiation of plantlets from callu

is the preferred approach for producing disease-free clones. The present intent is to determine modifications in cultural sequences required to tissue culture any remaining clones of *Populus* species and hybrids that may be considered for intensive culture. Presently available tissue-cultured poplar subclones will be used for virus inoculation studies designed to determine the effects of virus infection(s) on the performance of different poplar clones.

There are two possible ways to maintain virus-free *Populus* cultivars. A certification program of the kind commonly used to maintain virus-free potato varieties is one possibility. Such programs involve the production of disease-free clones of varieties, cultural isolation, and direct chemical control for protecting the foundation stocks from virus infections, continual indexing of the clones to detect symptomless virus infections, elimination of all infected materials from the foundation stock, and repeated inspections of a seed producer's fields as a requirement for certifying his seed potatoes essentially free of specified pathogens. This approach can be applied to *Populus* cultivars only after all the viruses infecting them become known and efficient indexing procedures for detecting them become available.

An alternative approach involves maintaining virus-free *Populus* cultivars as callus cultures. This would be the most inexpensive and the most effective method if *Populus* callus cultures remained genetically stable indefinitely and retained their potential for differentiating plantlets. Further research is needed to evaluate this possibility for clonal preservation.

Avoiding virus infections in field plantings will be much more difficult but possibly less important than avoiding them in the foundation stock. Starting with vigorous disease-free stock establishes an inoculum dilution factor and may reduce the time required for trees to attain the size at which substantial wood growth begins. Clones of many other crops have deteriorated slowly as a consequence of the gradual accumulation of infections by unrelated viruses, so new virus infections in plantings of disease-free poplar clones probably will not have a major impact on wood production, especially with the short rotations that are anticipated. Eliminating any plant species that may harbor poplar viruses from the vicinity of poplar plantations is the only practical control other than starting plantings with healthy stock. Although the new virus isolated from poplars probably is an exception, most known viruses of trees in the north-central States fortunately are not insect transmitted. Some of them are pollen transmitted, but transmission by this means within plantings of male *Populus* clones is not possible. Transmission by root grafting is not likely to occur with short rotations. Thus, the probability may not be very great of a rapid accumulation of damaging virus infections in poplar plantations that are started with healthy stock and grown for short rotations.

SUMMARY

1. Poplar species and hybrids are attractive candidates for intensive culture in the north-central region of the United States, but control of the many diseases and insects that may attack them is a prerequisite for success in their use for maximum wood fiber production.

2. Development of efficient crop production technology inevitably increases the extent of monoculture which, in turn, increases the vulnerability of the crop to damage by insects and diseases.

3. Infectious degenerative diseases, caused by viruses and other systemic pathogens, have developed in virtually all monocultures of vegetatively propagated agricultural and ornamental crops. Unless technology is developed and applied to avoid them, such problems are almost certain to develop in intensively managed monocultures of vegetatively propagated poplars.

4. Deterioration of unknown origin has been observed both in clones of Aigeiros poplars propagated by stem cuttings and in natural quaking aspen stands regenerated from root sprouts.

5. The isolation of an apparently new virus from both deteriorating Aigeiros poplar clones and an aspen clone supports the hypothesis that the poplar decline problem is caused by a virus or viruses. No causal relation, however, has yet been established.

Additional viruses probably will be found infecting poplars in the north-central region.

6. Research will be needed on the epidemiology of individual virus diseases of poplars to develop controls based on disease cycle interruptions.

7. The tissue culture technology already developed and applied to produce over 200 virus-symptomless subclones from 7 different virus-infected Aigeiros poplar hybrids and species of the Wisconsin collection can be extended to rejuvenate and to sanitize clones of other poplar species and hybrids that may be considered for intensive culture.

8. An unexpected variability in the growth potentials of symptomless tissue-cultured subclones of single clonal origins may provide an unusual opportunity for improving the biological efficiencies of poplar clones. However, approximately 10 percent of the tissue-cultured poplar subclones that have been evaluated at the University of Wisconsin showed conspicuous genetic damage.

9. If future research establishes that viruses, or other systemic pathogens, contribute significantly to the deterioration of vegetatively propagated poplars, a program designed to produce, to maintain, and to distribute disease-free stock would become a prerequisite for success in the intensive culture of poplars for maximum wood fiber production.

10. Significant clonal deterioration is not likely to occur in short-rotation plantings of poplars started with disease-free stock.

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IMPACT OF INSECTS ON TREES PLANTED FOR MAXIMUM FIBER PRODUCTION

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This report covers current and proposed studies of insect attacks and insect simulated damage to various clones of Populus. *Aphids were the most prevalent pests encountered. Other insects observed included leaf beetles, leaf hoppers, and assorted lepidopterous and coleopterous larvae. Aphids were injuring some of the tree's leaders. Local heavy defoliation was caused by larvae of the mourning-cloak butterfly. Simulated insect damage model proposed for next year is described in detail.*

This report describes a study of insect impacts on trees grown under intensive culture for maximum fiber yield and reports the first-year progress of the 3-year project The research is a cooperative effort of the Forestry Department at Michigan State University and the North Central Forest Experiment Station, USDA Forest Service.

OBJECTIVES

The overall objective is to assess the potential impact of insects on short rotation hardwood tree crops grown under intensive silvicultural systems. Attention is focused primarily on the genus *Populus*. Specific objectives in the several phases of the study are:

1. To prepare a bibliography of the existing literature on insects in relation to intensive silviculture.
2. To develop a computerized catalog of insects potentially damaging to *Populus* plantations, including identifying characters and type of damage.
3. To observe and document insect activity on *Populus* in nurseries, plantations and natural stands.
4. To assess probable impact of intensity and type of insect damage on tree growth and form.
5. To devise controls that might be used if infestations do develop.

REVIEW OF EXISTING INFORMATION

Wilson's review (In press) of entomological problems of forest crops grown under intensive silviculture, along with the references cited in it, provides an excellent point of departure for building an index file to the existing literature. Baker (1972) in his book on eastern forest insects condenses and reviews most of the pertinent literature through about 1969, and presents keys for identifying both insects and damage. Graham *et al.* (1963) provide a comprehensive treatment of the ecology and economics of bigtooth aspen (*Populus grandidentata* Michx.) and trembling aspen (*Populus tremuloides* Michx.) in the Lake States region including a rather complete discussion of the insect complexes associated with these two species. Morris *et al.* (1975) developed a handbook for ready reference to the major insect and disease pests of eastern cottonwood (*Populus deltoides* Bartr.).

Space does not permit a more detailed listing of the literature. However, a

comprehensive computerized index file is being assembled on the CDC 6500 computer system at Michigan State University. The file structure includes cross-referencing for retrieval by host, insect, or type of damage.

REFERENCE COLLECTION OF INSECT SPECIMENS

The project is assembling a reference collection of insects associated with *Populus* both in the nursery research plots and in natural stands. In general, the insects collected from intensively cultured plantations are typical of the complex described by Graham *et al.* (1963) for aspen sucker stands growing under less intensive management. A notable exception that will be discussed further in the next section, however, is the rarity of stem and branch borers. Identification of the specimens collected is continuing. Every attempt will be made to provide sufficient specimens for duplicate collections, one to be housed at the Forest Genetics Institute and the other at Michigan State University. The immature stages of the insects often cause most damage, so companion specimens of immatures and adults will be included wherever possible. Toward this end, attempts to rear immature forms through the adult stage will be increased during the second field season. Both collections will be arranged taxonomically within damage categories.

OBSERVATIONS OF INSECT ACTIVITY

Several studies being conducted at the Hugo Sauer Nursery facilitated comparing insect activity in *Populus* plantations with that in natural stands. A wide range of clones, spacings, and age classes are represented in the nursery, creating a cross-section of conditions that might be encountered in commercial production. All plots in the nursery were examined at irregular intervals, with some being checked every day. The nursery's insect control program precluded continuous collection, but collections were made just before spraying. Defoliators and sucking insects accounted for most of the damage in the nursery. Most prevalent were aphids, leaf beetles, leaf hoppers, and an assortment of lepidopterous and coleopterous larvae.

By far the most abundant and damaging insects in this cultivated situation were the aphids. Severity of attack by these insects ranged from just a few per plant to thousands, lending a blue-gray cast to the top 8 to 10 inches of the terminal leader. Clonal preferences seemed to be indicated, so a survey was made to verify this. Thirteen clones were evaluated for severity of attack by these aphids, tentatively identified as *Chaitophorus populifoliae* (Oest.). The results showed definite differences in severity of attack among some of the clones, corroborating the observations reported by Graham *et al.* (1963). The frequency with which aphids occur in *Populus* plantations, coupled with their potential for rapid increase, has led us to consider testing control by systemic pesticides.

Other insect damage in the nursery research plots was caused primarily by defoliators. Locally heavy defoliation was caused by larvae of the mourning-cloak butterfly, *Nymphalis antiopa* (L.), until controlled by chemicals. Several types of defoliation were observed, with windowpane damage by leaf beetle larvae being common. Insects appeared to concentrate on coppice stems that had been used to produce cuttings in the past, but the importance of this observation has not yet been explored.

Insect activity in less intensively managed stands was observed on the Nicolet and Ottawa National Forests. Areas visited on the National Forests were large (20 to 80 acres), logged-over areas that had formerly been occupied by aspen or aspen-hardwood mixtures but were now supporting young aspen suckers 3 to 7 years old. All districts were visited on both forests except the southernmost Lakewood District on the Nicolet National Forest. On both forests the type and severity of damage was very similar: mainly windowpaning, skeletonizing, and especially blotch mining. Two differences between the nursery plots and the aspen sucker stands were prominent: (1) unlike the nursery, few aphids were observed on the sucker stands; (2) galls were prevalent on both leaves and stems of sucker stands, whereas none were observed in the nursery. Reasons for the differences between nursery and sucker stands have not yet been pinpointed, but water relations and overall vigor are probably important.

DEVELOPMENT OF IMPACT MODEL THROUGH SIMULATED DAMAGE

The principal objective of this study is to assess the probable impact of intensity

and type of insect damage on *Populus* plantation growth. Other portions of the research program on maximum fiber production are designed to provide information on growth rates as a function of species, variety, spacing, fertilization, etc., in the absence of insect damage. Results of these other phases will be available for use in elaborating a growth impact model for insect damage. Given such background information on growth in the absence of insect attack, the goal is to develop an impact model of the general form:

> Impact = f(type of damage, severity of damage, timing of damage, competitive status of host plant).

In the context of this study, impact is taken to be failure to realize potential growth, assuming that control would be applied before significant mortality occurred.

The unique nature of the intensive culture environment and the variability of insect activity in natural stands preclude economically obtaining all the data needed to construct the model through observation of insect activity in natural stands. Furthermore, rearing a wide variety of insects on intensively cultured *Populus* material would be both difficult and expensive. Therefore, simulation of insect damage was chosen as the only practical approach to the problem. Even with simulation, however, it would be very difficult and expensive (if not impossible) to duplicate all details of damage by diverse insect pests, especially in the case of aphids, leaf rollers, leaf miners, and phloem feeders. Two physiological effects of insect activity on the plant, however, are of primary importance. One is removal or destruction of photosynthetic tissue through defoliation. The other is impairment of the conductive mechanisms of the plant as a consequence of girdling, boring, puncture wounds, etc. Therefore, a set of four controlled experiments was designed to provide the information on responses to these two general categories of damage.

The first experiment is designed to measure impact in relation to severity, timing, and recurrence of defoliation. The experimental design is a 3 by 3 by 2 by 2 factorial with two completely randomized replications. The first factor is degree of first year defoliation, with the three levels being set at 0 percent (control), 40 percent, and 80 percent. The second factor is degree of second year defoliation, with levels the same as for the first year. The third factor is timing of first year defoliation; early in the growing season or late. The fourth factor is timing of second year defoliation, with levels the same as for the first year. The layout for this experiment is a square planting of rooted cuttings from a single clone with 19 plants on a side and 2-foot spacing. With a two-plant buffer around the treated area to avoid edge effects, this layout provides five, three-plant plots across each width of the seedbed. As noted above, the locations of treatments and replications within the layout are completely randomized by three-plant plot. The 40 percent defoliation treatment is accomplished by removing the second and fourth leaf of every five along the length of the stem. The 80 percent defoliation consists of leaving every fifth leaf along the stem and removing the intervening ones. Response variables to be measured include height; diameters at ground level, 1 foot, and 4.5 feet; and total number of leaves. This experiment was installed in the Hugo Sauer Nursery on June 23, 1975. Planting stock consisted of 361 rooted cuttings of clone 5332 (*Populus ev. Betulifolia* X *P. trichocarpa* Torr. & Gray). Defoliation treatments were carried out on July 17, 1975, and August 23, 1975, with measurements being taken just before defoliation in each case. Eighteen of the 216 crop trees in this experiment died during the 1975 growing season. The cause of this mortality could not be determined; the leaves developed small necrotic areas that later expanded until the entire leaf died and dropped off. There was no evidence of insect activity, and no disease was identified.

The second experiment is designed to provide information on impact of defoliation in relation to clone and spacing. The design is a split-plot/factorial. Main plots are used to test 1- and 2-foot spacing. There are eight main plots with each of the two spacings randomly allocated to four main plots. A 3 by 2 factorial for clone and defoliation is nested in a completely random fashion within each main plot. The first factor is clone, with three clones representing the different levels. The second factor is defoliation, with one level being 0 percent (control) and the other being 75 percent defoliation effected by leaving every fourth leaf along the stem and removing the intervening leaves. Defoliation occurs in 1 year only, with response measurements being taken as described for the first experiment. The experiment was established on August 19, 1975. The clones used in this second planting are:

1--*Populus cv. Betulifolia* X *trichocarpa* Torr. & Gray (5332)
2--*Populus tristis* Fisch. X *P. balsamifera* L. *cv. Tristis* #1 (5260)
3--*Populus spp.* (5351)

Due to the late planting date, defoliation will be done during the 1976 growing season.

The purpose of the third experiment is to determine impact of girdling and boring damage and variability to be expected between clones. The design is a 6 by 3 factorial with two completely randomized replications. Five types of girdling and boring damage plus control constitute the six levels of the first factor. As in the first two experiments, plots consist of three rooted cuttings growing side-by-side in a row. The six types of girdling and boring damage are:

1. control (no damage)
2. 1/3 circumference girdled at 6 inches above the ground
3. 2/3 circumference girdled at 6 inches above the ground by a continuous slit
4. 2/3 circumference girdled at 6 inches above the ground by two opposing 1/3 slits
5. 1/8-inch hole bored straight through the stem at 6 inches above ground
6. two 1/8-inch holes bored straight through the stem at right angles 6 inches above the ground

Girdling is done with paired razor blades to make a double slit; the boring is done with a hand drill. All damage treatments are done in a single year, with response variables measured as for the first two experiments. The planting stock was propagated during the summer of 1975 and outplanted on August 19, 1975. The same three clones were used as for the second experiment. A 2-foot square spacing was used for the field layout. Treatments will be applied during the 1976 growing season.

The purpose of the fourth experiment is to find out how distribution of defoliation within the crown affects impact and whether there are clonal differences in this respect. This experiment has basically the same design as the third one, except that several mechanisms of achieving 75 percent defoliation replace the different types of girdling and boring injury. The defoliation treatments are:

1. leave every fourth leaf along the stem, removing the intervening ones
2. remove leaves on the upper 3/4 of the stem
3. remove every other leaf completely, then remove half of each remaining leaf by cutting at right angles to the midvein
4. cut every leaf in half as described in 3, then cut away half of the remaining half by cutting immediately to the right of the midvein leaving 1/4 of each leaf on the plant
5. remove leaves completely from top half of stem, then remove half of each leaf on lower portion as described in 3
6. control (no defoliation)

As with the third experiment, planting was done August 19, 1975, to ensure that the cuttings would be ready for treatment in 1976.

CONCLUSION

The various phases of this study including review of existing information, assembly of a reference collection, comparative observation of insect activity in *Populus* plantations and sucker stands, and controlled experiments with simulated damage should provide a good basis for assessing the potential impact of insects on hardwoods grown for maximum fiber production under intensive silviculture. Likewise, the results should help in deciding when to apply control measures and what type of control would be most effective.

It seems apparent at the end of the first year of study that defoliators and aphids are likely to account for most of the insect problems associated with intensive culture systems for *Populus* in the Lake States. Potential for use of systemic insecticides in controlling these insects will be part of the research program for the remaining 2 years of the study.

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ECONOMIC FEASIBILITY OF INTENSIVE CULTURES[1/]

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The application of intensive silvicultural methods holds great promise for increasing and sustaining supplies of fiber for the pulp and paper industry. Better information on harvesting and irrigation costs is required, however, for more conclusive statements about the economic feasibility of intensive cultures. To match sites with the best available management alternative and to optimally allocate limited funds to various sites and investments in intensive culture alternatives will require much improved growth information.

One definition of intensive culture is the management of forest crops via the use of management practices commonly found in agriculture. Included are the irrigation and fertilization of densely spaced, rapidly growing hardwood species for short coppice rotations. A high degree of mechanization and full-tree utilization are also characteristic of such "woody agri-systems." Within this definition of intensive culture, there is a considerable range in potential management intensity.

The ability to produce more fiber per acre than with conventional management techniques has been demonstrated, especially in the Southeast and the Lake States (McAlpine *et al.* 1966, McAlpine and Brown 1967, Gordon 1975, Ek and Dawson 1975). With fertilization and irrigation, yields of over 8 dry tons per acre per year (stem and branches only) can be expected in a 15-year rotation (Ek and Dawson 1975).

Because intensive silviculture will involve a high degree of mechanization and will require large capital investment, a real need existed to examine the economic feasibility of such systems under various conditions of the production site and production technology and to reduce the uncertainty to such levels that investment in intensive culture would involve an acceptable risk.

THE ECONOMIC MODEL

A complicating factor in analyzing the potential of intensive silviculture for production of fiber for pulp and paper or energy is the lack of information about the growth of intensively managed crops under a specific treatment regime and for specific locations. The primary focus of the economic analysis was, therefore, cost information on intensive culture for break-even analysis. The essence of such analysis is to determine for a specific production schedule and site the magnitude of physical yields (e.g., dry tons per acre per year) or financial yields required to just cover all incurred costs. Break-even yields can be expressed as (table 1):

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Table 1.--*Formulas for break-even calculations*

A. Minimum required value yields per acre at harvest age.

First Period:

$$TDC_1 = V_1/(1+i)^R; \; V_1 = TDC_1(1+i)^R \tag{1}$$

Second Period:

$$TDC_2 = V_2 \, (1+i)^{-(R+R_c)}; \; V_2 = TDC_2(1+i)^{R+R_c} \tag{2}$$

Under the assumption that costs and harvest yields are the same for each coppiced stand

$$V_{j+1} = TDC_2(1+i)^{-(j-1)R_c}(1+i)^{R+jR_c} = TDC_2(1+i)^{R+R_c}, \; j=1,2,\ldots n+1$$

Total Period:

$$TDC_A = \sum_{j=1}^{n+1} V_j(1+1)^{-(R+(j-1)R_c)} \tag{3}$$

If the minimum *average* required yield at each of (n+1) harvests that would cover total discounted costs is to be calculated, equation (3) must be solved in terms of $V(v=v_1=v_2= \ldots v_{n+1})$ which results in:

$$V = (TDC_A)(M) \tag{4}$$

where M is the multiplier

$$M = (1+i)^{(n+1)\,R+\sum_j^n jR_c} / \sum_{k=1}^{n+1} (1+i)^{nR + \sum_j^n jR_c - (k-1)R_c}.$$

TDC_A = total discounted costs per acre from establishment to last harvest of stand before reestablishment through planting.

TDC_j = total discounted cost per acre of harvest period j, j=1,2, ...n+1.

R = rotation age of planted stand.

R_c = rotation age of coppiced stand; n coppicings.

i = discount rate.

V_j= minimum required (total value yield per acre from harvest at the end of period j (year $R+(j-1)R_c$) to cover the costs of the investment or total compounded costs during period j.

V = minimum average required value yield per acre at each of (n+1) harvests at the ages $R + (j-1)R_c$.

B. Minimum required annual value flow from each acre.

Because presently required minimum value yields for period j and the total production period are simply equal to the respective discounted costs for the period or

$$V_{jp} = TDC_j \text{ and } V_p = TDC_A, \; j=1,2,\ldots n+1,$$

annually required yields per acre can be obtained by multiplying them with a "cost recovery factor" RF:

$$RF = \frac{i(1+i)^t}{(1+i)^t-1} \quad \text{where } \begin{cases} t = R \text{ for period 1} \\ t = R_c \text{ for periods } 2,3\ldots n+1 \\ t = R + nR_c \text{ for the total period} \end{cases}$$

V_{jp} = minimum value yield per acre required at present to cover production costs for period j.

V_p = minimum value yield per acre required at present to cover costs for the total period.

RF = cost recovery factor.

(1) Minimum required yield per acre per year or the required annually compounded revenue or volume flow.

(2) Minimum required yield per acre at the time of harvest. This required yield is equal to the total compounded costs per acre.

The latter is a more useful management guide because it is at the time of harvest that final yields are being realized. If coppicing takes place, the same stand would go through another production period, usually involving lower expenditures because initial site preparation is no longer necessary. Break-even yields can, therefore, be calculated for the first period comprising all costs from initial establishment to the first harvest, for the second period (from first coppicing to the harvest of the coppice stand) and similarly for the third, fourth, etc., periods.

It is possible to calculate a minimum *average* yield per acre at each of a number of consecutive harvests (not necessarily at equal time intervals) over a production cycle that is required to cover total production costs. *Average* compounded costs per acre at each harvest are the basis for this criterion and can be obtained by solving equation (3) in table 1 for V, average compounded costs per acre each harvest.

This break-even yield, being a weighted average of the minimum requirements for the individual harvest periods, usually will fall between the break-even yield for the first and the following periods and will decrease with the number of coppicings.

The computer program developed for break-even analysis is a cost accounting system; i.e., a system that keeps a record of the magnitude of costs incurred and the time at which expenditures occurred (Rose 1975). The model has, however, a number of other features that make it useful for detailed production planning. A discussion of some of these features will be postponed until the major model inputs have been described. These are:

(1) Condition of the site.--This determines the type of land clearing and site preparation activities necessary for intensive cultures.

(2) Management plan.--The program can simulate any management plan or activity schedule. A plan specifies the type of activities to be applied and the time and frequency of their application.

(3) Rotation ages for planted and coppice stands.--Because coppiced stands have an already existing root system, rotations might be shorter for such stands.

(4) Number of coppicings.--This indicates how often a stand can be harvested without replanting.

(5) Plant size or total acres to be managed intensively.--The model will establish a sustained yield operation. If a rotation of, say, 3 years is used for planted stands, one third of the total acreage will be put into intensive culture each year for 3 years. After one rotation, a sustained harvest of one third of the acreage will be possible.

(6) Stand stocking or tree spacing.

(7) Interest rate or alternative rate of return.

(8) Annual administration costs (including taxes) per acre.

(9) Land cost per acre.--Land cost can be incorporated either as an annual rent or as purchase cost per acre. A resale value of the land can be specified if the land is sold after the production cycle. The purchase cost and resale value of the land are converted into annuities over the production cycle by applying the "capital recovery" and "sinking fund multiplier," respectively. The difference between the two values is the annual land cost per acre.

(10) Assumed delivered value of a dry ton of fiber.

(11) Assumed mean annual growth in dry tons per acre for planted and coppice stands.

(12) Annually compounded real rate of price changes of the product and/or costs.

(13) The cost per acre for all activities used in the management plan.--The program accepts either a specified cost per acre or calculates such a cost from a short-run average cost curve for the activity from internally stored information on a large number of machines used in such production systems. For the latter option, fuel costs, machines, machine production rates, and yearly time constraints on the activity (in hours) have to be specified to facilitate calculation of the average weighted cost per acre for the machines handling the specific job. With this option, economies and diseconomies of scale will be simulated, depending on the scale of the operation, the time constraint, and the machine productivity. A suboptimization should be attempted outside the model in the selection of efficient total machine packages.

Break-even yields are only one of the outputs produced by the model. These re-

quired yields are given separately for the first, second, and total period. The latter is recorded for one harvest block and also for the total sustained yield system (all harvest blocks) to show any economies of scale that might result from a higher utilization of machines.

If a product value (dollars per dry ton of fiber) and a mean annual growth can be estimated, present net worth and internal rate of return are also calculated. Among some of the other outputs useful for production planning are tables showing machine production statistics, annual acreage on which various intensive culture activities are scheduled, associated machines by type and number, machine hours, costs, replacement schedules, and capital requirements. Capital requirements must be considered upper estimates because machines such as tractors can be used for more than one activity during the nonoverlapping working periods. Total discounted costs for each activity and their relative importance are described.

The program can be executed in an interactive mode. Management decisions can, therefore, be improved from one run to another by simply changing any of the previous inputs or factors, especially those that in practice would be under the control of the manager. The model thus lends itself well to analysis of the factors to which break-even yields are most sensitive.

ESTIMATION OF PRODUCTION COSTS

Cost estimating is at the heart of break-even analysis. Various estimates of production costs in intensive cultures are available (Briscoe 1969, Dutrow *et al.* 1970, Dutrow 1971, McKnight 1970, Olawoye 1972, DeBell and Harms 1975, Sunda and Lowry 1975). Some of these sources have become outdated due to inflation and changing technology.

Table 2, largely based on information by DeBell and Harms (1975), and somewhat modified by the authors, describes the range within which various activity costs might be expected to fall, but is not useful for analyzing specific production situations.

Because mechanization will play a substantial role in intensive culture, it is essential to estimate machine operation costs for specific site conditions and scales of operation; i.e., to develop short-run average cost curves. Such curves illustrate how per-unit costs change with different levels of operation.

Table 2.--*Intensive culture costs*[1/]

Type of cost	Definition	Average	Low	High
Land	Land rent	40	20	80
	Land purchase	800	400	1,200
Establishment	Land preparation			
	Mature forest	250	200	300
	Plantation	150	100	200
	Pasture	55	30	80
	Cropland	10	5	15
Management	Planting			
	2 by 4	140	125	155
	4 by 4	85	75	95
	6 by 6	55	45	65
	12 by 12	15	10	25
	Management			
	Admin. (Annual)	3	2	4
	Fertil. (Periodic)	75	25	150
	Weed & Prot. (Rotation)[2/]	20	10	30
	Harvesting-Hauling			
	2-year rotation	80	40	160
	4-year rotation	160	80	320
	10-year rotation	400	200	800
	Rejuvenation	25	10	160
	Regeneration	70 + Planting (varies with spacing)		
	Rehabilitation	70	60	80

1/ Adapted from DeBell and Harms (1975) with some modifications.
2/ Initial weed control included in land preparation costs.

Short-run average cost curves were derived from information collected for the various agricultural and forestry equipment that might be used in intensive silviculture (fig. 1). The relation of cost economies to annual operational size of intensive cultures is of special interest because cost economies will likely be greatest in large units and with full utilization of machinery.

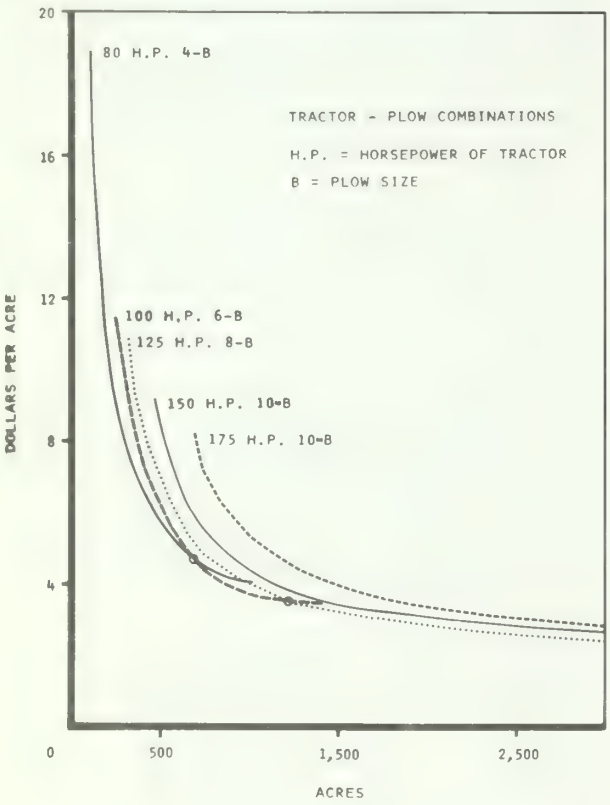

Figure 1.--*Short-run cost curves for plowing.*

Costs per acre decline over all acreages because fixed costs are spread over more acres while variable costs tend to be constant; costs per acre are based on near-linear relations (Heady *et al.* 1955). A different short-run curve exists for each level at which identical factors may be held fixed (e.g., two or more tractors instead of one) or for each possible form of fixed factors (e.g., a large tractor as compared to a small tractor).

Curves for cost per unit of product would be similar to the curves in figure 1 (fig. 2). The curves SAC represent short-run costs for various machine combinations. As production increases for the variable factor or as fixed costs are spread over a greater output, the

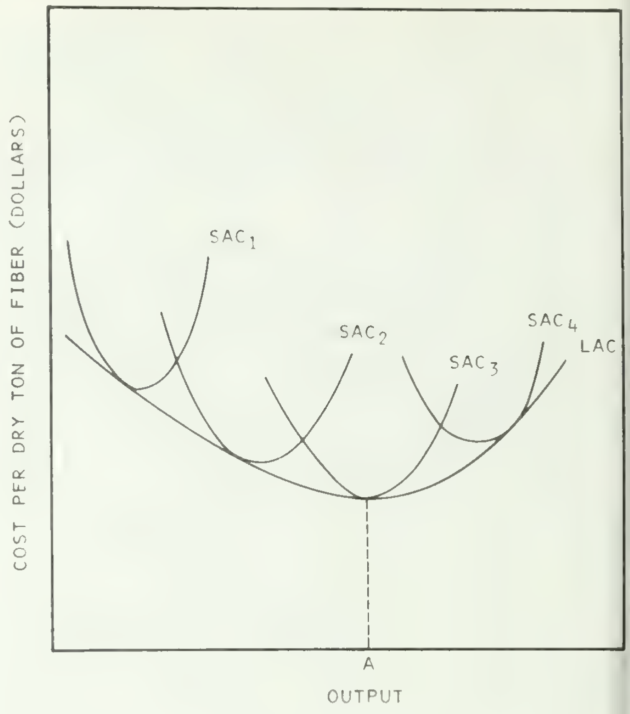

Figure 2.--*Family of short-run cost curves and their envelope.*

cost per unit of output declines. But contrary to the curves in figure 1, costs per unit of product may eventually rise because operation of a machine (combination) on an increasing acreage will eventually lead to untimely operations with resulting lower per-acre production rates and, therefore, higher operating costs. Costs per unit of product increase as soon as production rate decreases and operation cost increases offset further declines in fixed machine cost per unit.

Out of an entire family of short-run cost curves, one particular curve has a minimum point lower than that of any other curv (fig. 2, point a). At that point, the indicated output could be produced at lower per-unit cost than with any other factor combination and represents the optimum production level.

A long-run cost curve for which no single resource is fixed can be constructed for any family of short-run cost curves. It is the "envelope" of the short-run cost curves; i.e., it is tangent to each single curve at one point. Individual short-run curves that have their tangency either to the left or right of their minimum point would represent nonoptimal factor combinations. The short-run curve that is tangent to the long-run curve at its minimum point is the optimal factor combination and short- and long-run average costs are minimum at that point.

COMPARISON OF TWO BASIC ALTERNATIVES

Two basic intensive culture alternatives were selected to describe the range of intensive culture philosophies from extreme short rotations with numerous coppicings to longer rotations without coppicing (table 3). The costs for the various intensive-culture activities are our best estimates at this time and based on available literature and various other sources. Costs for land clearing, piling, and disking (site preparation) were estimated from the long-run cost curve for these activities (figs. 3, 4, and 5). Envelopes were hand drawn to the short-run cost curves for the various activities to derive the respective long-run cost curves (fig. 6). The total long-run cost curve is simply the vertical summation of the long-run cost curves for individual activities (fig. 7). Cost assumptions for the alternatives are summarized in table 4.

Six selected results are reported for each computer run (table 5). It is apparent from the first two runs of each alternative (analyses 1 and 6) that the extreme short-rotation alternative does not offer any investment opportunity under the assumed costs, yield, and product price. The 15-year rotation, on the other hand, offers positive rates of return on the investment, but irrigation does not appear to offer any advantage in the current context.

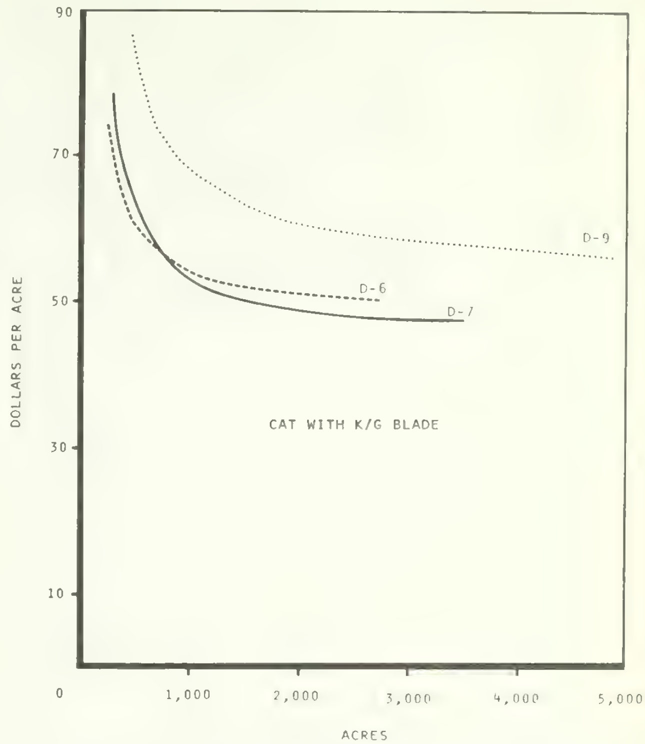

Figure 3.--*Short-run cost curves for land clearing.*

ADDITIONAL COMPARISONS

The number of management alternatives and estimates of production costs, yields,

Table 3.--*Two basic intensive culture alternatives*

	Alternative I	Alternative II
Rotation (no.)	5	15
Coppicings, no.	3	0
Spacing (ft.)	4 x 4	12 x 12
Discount rate (percent)	10	10
Price per ovendry ton, delivered (dollars)	30	30
Growth (tons per acre per year)		
(a) without irrigation	2.5	4.5
(b) with irrigation	4.0	7.8
Annual harvest acres (sustained yield operation)	1,000	1,000
Activity	**Year(s) in which activities take place**	
Land clearing	1	1
Site preparation	2	2
Planting	2	2
Weed control	2,7,12,17	2,3
Fertilization	2,4,7,9,12,14,17,19	2,5,8,11,14
Harvesting-hauling	6,11,16,21	16
Irrigation setup	2	2
Irrigation (maintenance and operation)	2 to 21	2 to 15

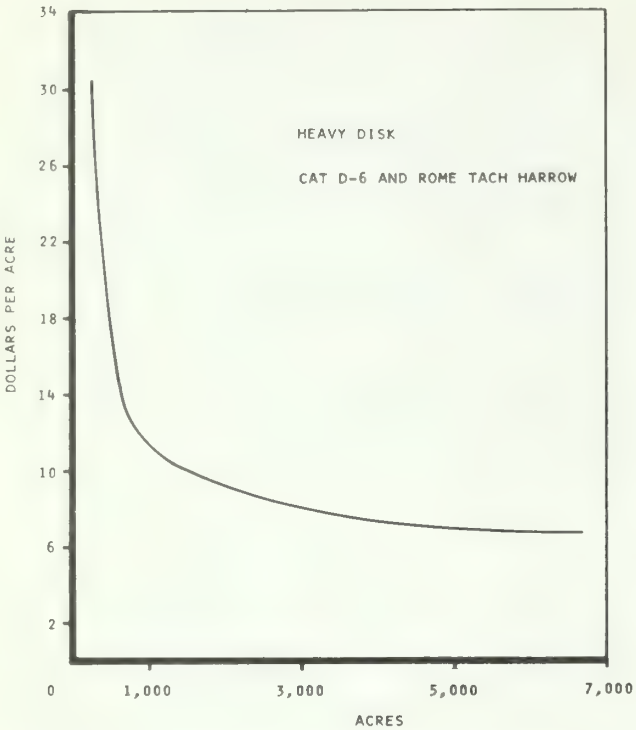

Figure 4.--*Short-run cost curve for heavy disking.*

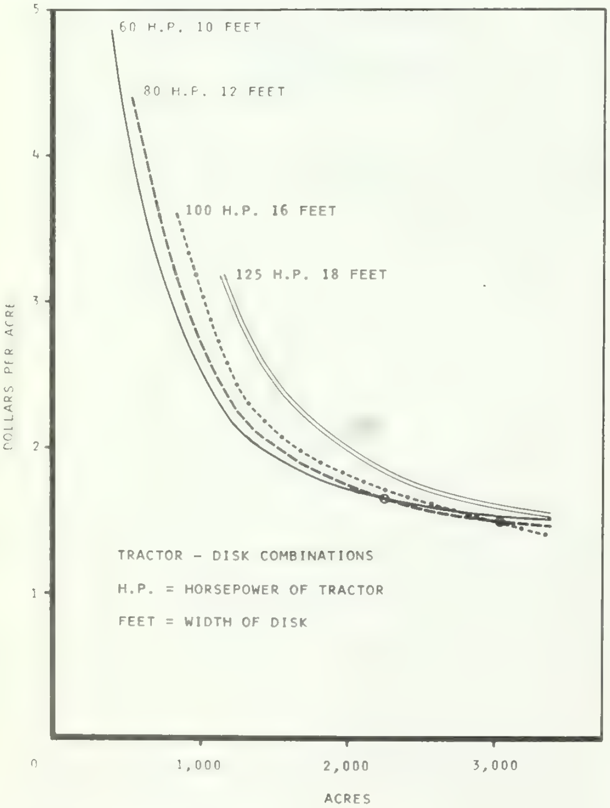

Figure 5.--*Short-run cost curves for agricultural disking.*

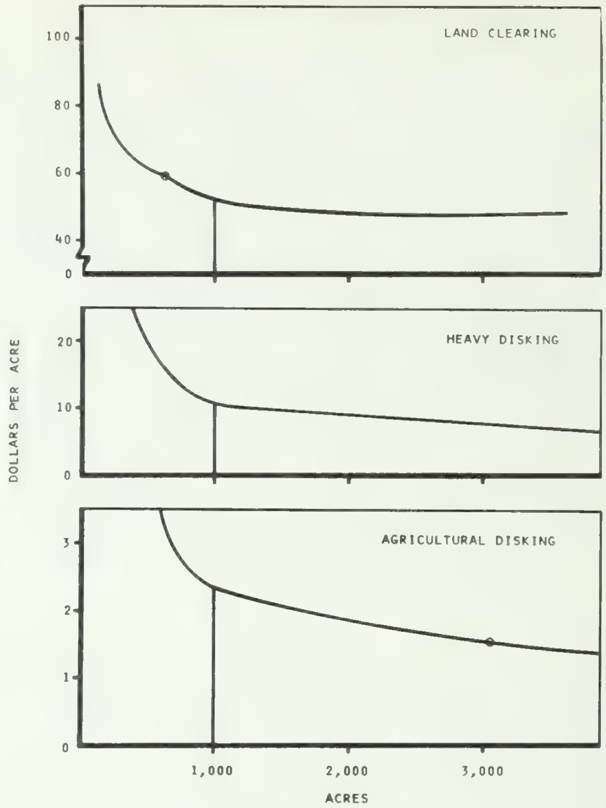

Figure 6.--*Long-run cost curves for land clearing, heavy and agricultural disking.*

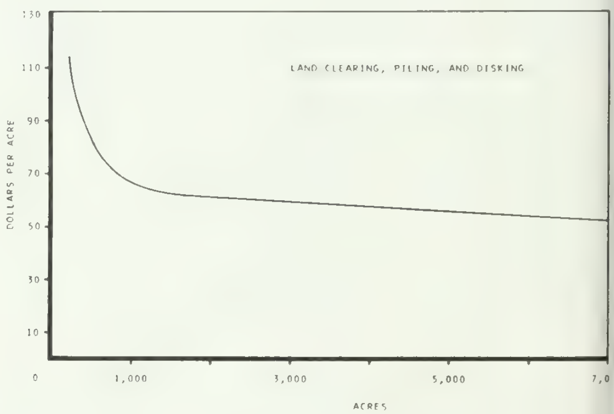

Figure 7.--*Total long-run cost curve for land clearing and other site preparation activities.*

and prices is much too large to allow complete testing of all possible combinations. Fortunately, break-even requirements for a given alternative and cost combination, after changing cost and/or price assumptions, can be calculated without additional computer runs.

The adjustment procedure is simply to multiply the change in total discounted costs per acre due to any cost change by the multiplier M from equation (1) to obtain the adjustment in the average break-even requirement over all individual harvests. To facilitate further sensitivity analysis, table 6 was constructed. It states the multiplier for selected alternatives and the magnitude of adjustments in break-even yield for selected cost changes.

Table 4.--*Cost of two intensive culture alternatives*
(In dollars per acre)

Activity	Alternative I	Alternative II
Land clearing	62	62
Site preparation	2.60	2.60
Planting	85	15
Weed control	14	14
Fertilization	55	55
Harvesting-hauling	250-350	400-600
Irrigation setup	400	400
Irrigation (maintenance and operation--annual)	40	40
Administration costs (annual)	3	3
Land rent (annual)	10	10

The sensitivity of break-even yields to a change in annual costs obviously increases with the length of the rotation. Similarly, the sensitivity of break-even yields to any one-time cost change is greater, the earlier this cost occurs in the production period. In contrast, a change in harvest costs (or any other cost occurring in the last year of the harvest cycle) will affect break-even requirements equally over all alternatives. Any other cost change that occurs at the same time for any alternatives (such as 1, 2, etc., year(s) before a harvest) will change break-even yields equally over such alternatives.

Table 5.--*Economic analysis of two basic alternatives*

Alternative	Analysis	Required mean annual growth	Required yield per acre each harvest	Cost per dry ton of fiber production	Present net worth per acre	Internal rate of return	Payback period	Assumed yield per acre per year	Remarks
		Dry tons	*Dry tons*	*Dollars*	*Dollars*	*Percent*	*Years*	*Dry tons*	
I	1	4.05	20.26	48.63	-295.16	<0	N	2.5	No irrigation
	2	8.09	40.43	60.64	-776.86	<0	N	4.0	Irrigation[1]
	3	7.27	36.36	54.53	-622.07	<0	N	4.0	Irrigation[2]
	4	6.46	32.29	48.43	-467.28	<0	N	4.0	Irrigation[3]
	5	4.72	23.59	35.39	-136.70	1.9	N	4.0	Irrigation[4]
II	6	4.30	64.45	28.94	19.92	10.6	16	4.5	No irrigation
	7	10.94	164.11	42.08	-307.59	6.1	N	7.8	Irrigation[1]
	8	9.53	142.93	36.65	-169.30	7.8	N	7.8	Irrigation[2]
	9	8.12	121.75	31.22	-31.01	9.6	N	7.8	Irrigation[3]
	10	4.74	71.12	18.23	299.57	16.4	16	7.8	Irrigation[4]

1/ Setup cost \$400, maintenance and operation \$40 per acre per year.
2/ Setup cost \$400, maintenance and operation \$20 per acre per year.
3/ Setup cost \$400, maintenance and operation \$0 per acre per year.
4/ Setup cost \$0, maintenance and operation \$0 per acre per year.

Table 6.--*Sensitivity in break-even requirement to changes in various costs*[1]

Alternative	Multiplier	Change in break-even requirement for a 10-dollar-per-acre change in: Annual cost	First-year cost[2]	Fertilizer cost	Harvest year cost
I	0.7888	68.22 dollars	7.17 dollars	29.41 dollars	10.00 dollars
		[3] 2.27 tons	.24 tons	.98 tons	.33 tons
II	4.5950	359.50 dollars	41.77 dollars	127.79 dollars	10.00 dollars
		11.98 tons	1.39 tons	4.26 tons	.33 tons

1/ All calculations based on 10-percent discount rate.
2/ A \$10 change in a second, third, etc., year cost is equal to the discounted value of a first-year cost change.
3/ Based on a price of \$30 per ton.

Clearly, break-even requirements must change linearly with changes in a cost factor, and all break-even yields can be generated for any level of that cost factor once one solution has been found (figs. 8, 9, and 10). Furthermore, any cost change--be it an annual, periodic, or a one-time cost--will cause a parallel shift of a specific break-even line.

For further information on the feasibility of any given management alternative, graphs as in figures 8 and 9 can be constructed with the cost factor on the X-axis that is most critical or for which the information is the least complete. Figure 8 thus provides information on how low harvesting costs would have to be to make the alternative economically feasible.

The effect of a change in the product price is the easiest to predict because break-even yields (in tons) are inversely proportional to price; i.e., a doubling in product price will reduce break-even yields by 50 percent. The absolute effect of any price change on break-even yields is greater

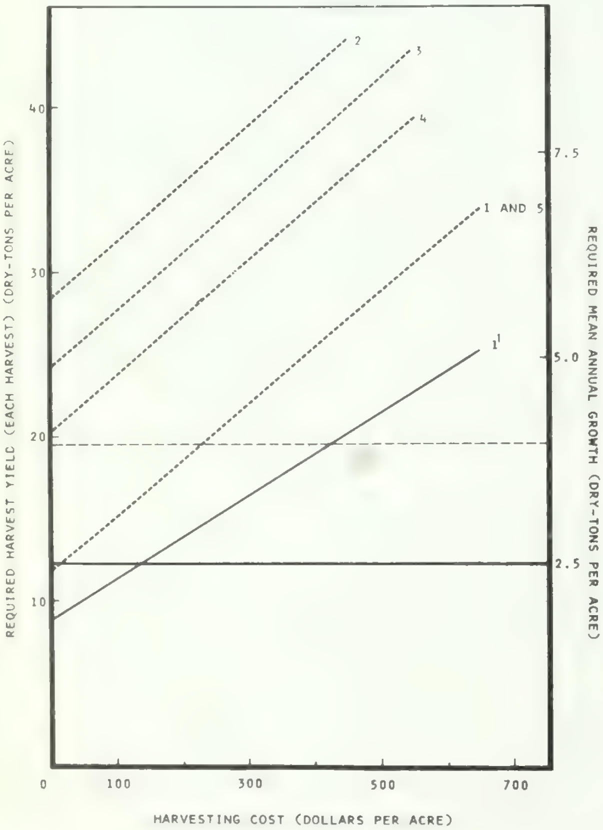

Figure 8.--*Break-even yields for short-rotation alternatives.*

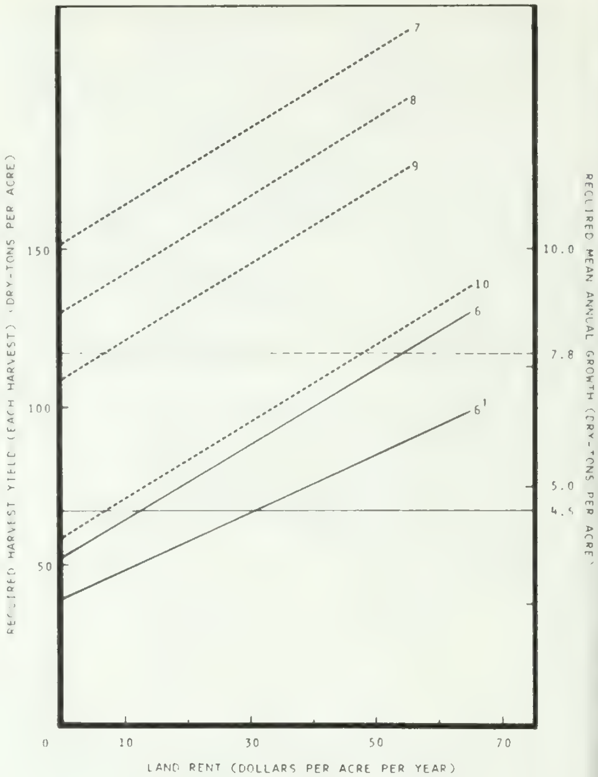

Figure 9.--*Break-even yields for long-rotation alternatives.*

for higher break-even yields. Price changes therefore, cause changes in the slope of break-even relations, leading to a change in the relative importance of all other cost factors (figs. 8 and 9, lines 1^1 and 6^1).

The assumed yield itself does not influence break-even requirements and is drawn into the illustrations as a horizontal line (figs. 8 and 9). The intersection of this line with any break-even line represents the point at which the internal rate of return is equal to the specified discount rate or at which present net worth is zero. Any solution to the left of the intersection would have a positive present net worth and an internal rate of return greater than the selected discount rate. Net income (tons) at the time of harvest is represented by the vertical distance between break-even yields (cost-) and yield- (revenue) lines.

IRRIGATION--POLLUTION ABATEMENT TRADE-OFFS

One of the interesting considerations in intensive culture is the possibility of charging the cost of irrigation against the

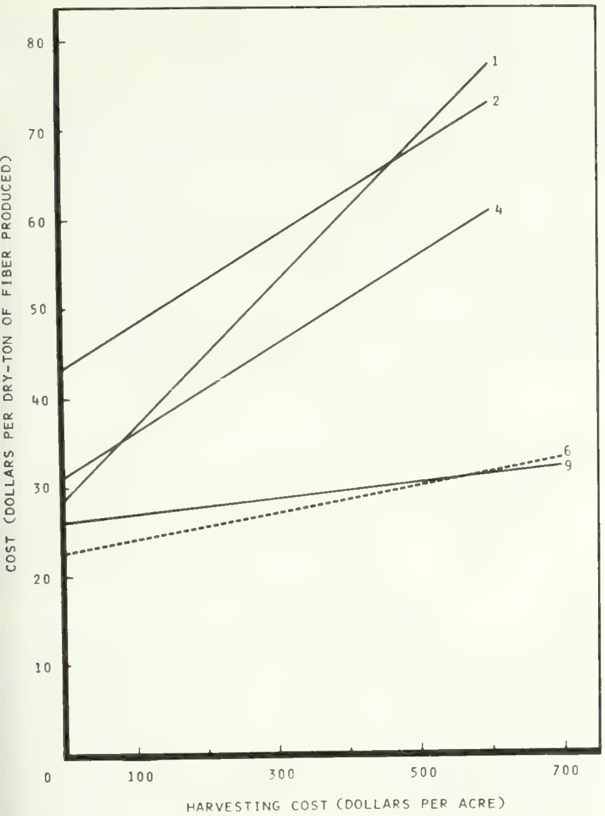

Figure 10.--*Fiber production costs for selected alternatives.*

cost of cleaning up polluted effluent. Timber industries involved in both timber production and production of pulp and paper will be faced with new and stringent standards for the quality of effluent. The Water Pollution Control Act of 1972 (PL92-500) charges industry with zero discharge by 1985 and will require strict pollution abatement standards. These legal requirements will increase production costs substantially, and the implications are especially severe if discharge even of treated effluent is not possible; i.e., discharge on land is required.

With zero-discharge interpreted literally, irrigation of crops would become a free byproduct with no cost to the forest manager. Even if the irrigation setup, maintenance, and operation costs are charged against the irrigated crop, these costs should be properly reduced by savings in operating pollution abatement systems, by savings in fertilizer costs (due to possible soil-improving characteristics and the nutrient content of the effluent), and by increases in crop yields due to irrigation. Pollution abatement costs could be reduced if irrigation is possible with effluent that has gone only through some of the cleanup stages, such as primary treatment, with savings to be realized mostly in operation of secondary and other cleanup stages. The capital facilities for all treatment stages must, however, be available in case irrigation has to be disrupted, such as during the winter in northern climates.

If effluent is used for irrigation after going through the primary clarification, the annual savings in operating biological clarification and secondary clarification could run around $225,000 for a large pulpmill (100-ton per day capacity). Biological oxidation might be necessary to eliminate offensive odors near residential areas. Savings would then be only about $50,000. At $40 per acre for maintenance and operation of an irrigation system, 1,250 acres could be irrigated without cost to the forest sector by writing these costs off against the savings in pollution abatement.

If such cost savings can be realized, break-even yields will change substantially (figs. 8 and 9, table 2). The irrigation-pollution abatement trade-off has to be large, however, before irrigation would become economically feasible and more profitable than the no-irrigation alternative.

HARVESTING COSTS

One of the most difficult to estimate costs in intensive culture is the harvesting cost, because it depends on the conditions of the terrain, on the characteristics of the stand, the harvesting system, and the scale of the operation. Published harvesting costs provide, at best, only a range in harvesting costs for traditionally managed stands in a variety of locations (Zasada 1971, Anderson and Granskog 1974, Biltonen *et al.* 1974, Biltonen and Steinhilb 1975). These and other sources give information on old and new harvesting systems in the Lake States. It is not possible, however, to strictly apply such cost estimates to intensive cultures. The latter will differ greatly from traditionally managed stands in terms of stand characteristics such as volumes per unit area, tree spacing, and tree size distribution. For the longer rotations, savings might be possible with highly mechanized and properly balanced total harvesting systems.

For extremely short rotations, even fewer harvesting cost estimates are available. However, harvesting young stands

with techniques developed for older stands would probably be too costly because of the large amount of small material to be handled. Agricultural type machinery, such as forage harvesters, has been suggested and tested, however, with some success, and harvesting costs with such cheap equipment could be much lower than assumed in this study (Dutrow 1971). Our estimate from the long-run cost curve for a single-row forage harvester driven at 3 m.p.h. and operating 1,000 acres per year is $25 for the 4 by 4 spacing. Much better information based on actual field trials is necessary, however, before conclusive statements are possible. With harvesting costs as low as indicated above, the extreme short-rotation alternative would become economically feasible (fig. 8).

THE MANAGEMENT PROBLEM

One of the major problems facing large pulp and paper mills is getting a continuous supply of fiber to the production facility. Most mills depend on outside suppliers but also manage their own wood holdings for the continuous production of fiber. To match management practices to the conditions of the site through species selection, rotation determination, intensity of management, and degree of mechanization, the industry forester must know the site factors and their influence on costs and revenues.

A useful first step in identifying suitable management alternatives for a site is to classify the land according to biological, physical, and socio-economic criteria. The classification system must describe the factors that most significantly affect the biological and economic feasibility of intensive cultures. But at the same time, a compromise is required between the detail of such a classification scheme and the cost of measuring its components. The site index as a measure of growth potential must be refined to show the growth potential under various degrees of fertilization and irrigation. Climate, terrain, and soil conditions determine the potential for irrigation and mechanization. Accessibility is an important economic factor in harvest and hauling operations. Land rents will reflect the potential productivity of a site.

For areas that are similar in terms of biological productivity, soil and terrain, production costs, and markets, the second step is to design alternative management approaches and identify associated costs and revenues. An economic production equivalent value that quantifies the net return of a site for various management approaches was used by Rust and Hanson (1975) to rate crop equivalents of Minnesota soils. The third step involves ranking and comparing alternatives according to one or more management criteria. The final step involves implementing the chosen alternative. These steps are fairly standard in any investment analysis. A complicating factor is the lack of information about the growth of intensively managed forest crops.

Break-even requirements for various sites and available management options must be compared to the yield that is likely on the site for the assumed management intensity (table 7). Yield of natural stands on the site can serve as a conservative estimate of a site's growth potential for comparing with break-even yields, if better growth estimates cannot be obtained for intensive culture regimes. A good clone, however, could produce less than a natural stanc if moved out of its optimal environmental conditions, especially if it has a narrow range under which it performs well. Such considerations will be essential in judging the economic feasibility of a management alternative.

Table 7.--*Comparison of required and expected mean annual growth (hypothetical)*
(In dry tons per acre)

PRICE--25 DOLLARS PER TON

Location					
A		B		C	
Required	Expected	Required	Expected	Required	Expected
4.04	4.0	4.04	4.0	4.75	5.0
5.38	5.0	5.38	5.0	6.08	6.0
5.27	6.5	6.61	6.0	8.31	6.5
5.60	7.5	7.96	7.5	9.66	8.0
PRICE--30 DOLLARS PER TON					
3.37	5.0	3.37	4.0	3.96	5.0
4.48	5.0	4.47	5.0	5.06	6.0
4.39	6.5	5.51	6.0	6.92	6.5
4.67	7.5	6.63	7.5	8.05	8.0

Personal experience, professional consultation, and yield tables of managed and unmanaged stands must be used to obtain poi or internal estimates of potential yields a to identify promising and infeasible altern tives. The hypothetical growth estimates i

table 7 are assumed to be the result of such an approach. With this information, location A would have been selected on that basis as a promising site for irrigation and fertilization, but the same management intensity would have been found infeasible on site C or B.

The greater the difference between estimated yields and break-even requirements, the smaller the production risk would be, assuming all yield estimates are equally reliable. The alternative with the smallest risk would not necessarily be the best in terms of other investment criteria, such as present net worth and internal rate of return. The latter can, however, only be calculated if product values, as well as fiber yields, can be estimated. Without such knowledge, a decision must be based on the economic feasibility and risk of an alternative.

If break-even yields for an alternative are higher than known or estimated potential yields, the alternative must be discarded for the area under investigation. Economic feasibility might be achieved by reducing the intensity of intensive culture management, leading to lower break-even requirements. The question then is whether the cost reduction (or break-even yield reduction) more than outweighs the potential reduction in yield. It is through a series of such steps that land management zones or classes can be identified. For each zone, management plans that are economically feasible and infeasible can be stated. Zones will be ranked by their suitability for intensive culture and opportunity for investment.

Because any given cost estimate has a rather large error, zones will share areas of overlap for which the economic feasibility of a management plan is of greater uncertainty. One procedure to quantify further the risk of an investment is, therefore, to change individual costs that show a large degree of variability and/or that are least known, so as to identify the sensitivity of break-even yields to such a change. This procedure is illustrated in table 7 for a price change from $25 per ton to $30 per ton.

SUMMARY AND CONCLUSION

The intensive culture of woody species has created widespread interest because of threats of timber shortages and the demonstrated economic and biological potential of intensively managed species. It is essential to identify the locations best suited for intensive culture and select the management intensity that is best in terms of a selected economic criterion. Because yield information is still limited, break-even analysis was suggested as an initial selection criterion. Because yield information is not used in this measure, it is a less powerful tool than other economic criteria that include yield; e.g., present net worth or internal rate of return. Future research efforts must emphasize growth and stand treatment studies and focus on some of the critical cost factors that were identified.

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UTILIZATION ADVANTAGES OF MATERIAL PRODUCED IN MAXIMUM FIBER YIELD PLANTATIONS

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The usual justification for agronomic systems of fiber production is to greatly increase yields to meet future fiber shortages. However, the material produced should have utilization advantages over typical rough wood chips by having reduced grit and deleterious bark cell contents. Efficient harvesting and processing will be possible because of great uniformity in the material derived from control over genetics, environment, and age. Efficient processing should help overcome low pulp yields and strengths characteristic of juvenile material.

The usual justification for agronomic systems of fiber production is to greatly increase yields to meet future fiber demand. However, agronomic fiber production has many other advantages from a utilization standpoint. This paper deals with those advantages.

The key to these advantages is efficiency. Recently, forest utilization has become more efficient through the adoption of whole tree utilization. Here all aboveground portions of the tree are harvested and used, sometimes doubling yields. This has been accomplished by the development of machinery that chips whole trees at the landing and the utilization of rough wood chips (those containing bark) at the mill. Moreover, under this system harvested areas are cleaner, more esthetically pleasing, and cheaper to regenerate. And trasportation and handling costs are less than for conventional harvesting practices.

However, whole tree chipping has created some new problems, particularly at the mill. Lifespans for equipment are shortened because wear and erosion are accelerated by increased amounts of dirt and grit included with whole-tree, rough wood chips. Grit becomes lodged in the bark from skidding whole trees to the chipper, especially during muddy seasons. More mill equipment, such as washers, screeners, and centricleaners, is needed to remove the increased grit load from pulp furnishes. Bark itself causes problems in pulp furnishes by reducing pulp yield, strength, and cleanliness. Often additional digestor capacity, used liquor recovery capacity, and centricleaners are needed to handle the bark. Nevertheless, the additional yields from whole tree chipping offset mill disadvantages, and when crisis shortages occur, as is already happening in many areas, mills would rather run on less than desirable furnish than not run at all.

Maximum fiber yield systems can reduce or circumvent most of the major mill problems associated with typical rough wood chips and still retain and enhance most of the advantages of whole tree utilization.

Let's examine the grit problem. Wood procurers dream of some huge machine that would travel over the land and cut and chip trees as it moves. An extremely complex and expensive piece of machinery would be needed to handle trees of all sizes over

rough terrain. Also, chip mixtures arriving at the mill would vary with the compositions of the harvested stands. Varying chip mixtures complicates pulping because pulping conditions must be changed to accept them.

Plantations of trees grown in maximum fiber yield systems are ideal for moving harvester-processors. The plantations will be on good sites that are nearly level, precluding problems with rough terrain. Furthermore, the trees will be nearly uniform in size and grown at regular spacings. These factors allow for efficient machine design. Trees less than 3 years old can be harvested with beefed-up forage harvesters, but specialized harvesting equipment will be required as trees grow larger. The new moving harvester-processor may incorporate the helical head chipper developed at the North Central Station's Forest Engineering Laboratory.

Why all the discussion of moving harvester-processors? If trees can be cut and chipped without ever hitting the ground, skidding would be eliminated and hence grit picked up during skidding would no longer be a problem at the mill. Until such machines are developed, grit problems can be reduced by cutting and skidding only when the ground is dry or snow covered.

Other advantages derived from maximum fiber yield plantations and harvester-processors include improved logistics of mill supply and better chip quality. Greater yields in maximum fiber yield plantations require less land to supply a mill. This land could be close to the mill and the harvester-processors would be able to operate nearly all year. Then mill yard inventory can be greatly reduced. When furnish is needed, it can be readily cut and quickly transported. Less mill yard inventory requires less capital and chips will be of higher quality because they have had less time to be degraded by pathogens during storage.

How about problems associated with bark? Bark is an extremely heterogeneous mixture of many cell types and shapes--much more complex than wood. Yet most cells in bark are not extremely detrimental to pulp and paper making. The most troublesome cells are commonly called stone cells, a small fraction of bark, yet their presence has given all bark a bad reputacion. Stone cells are blamed for plugging paper machine wires, causing poor drainage and sheet formation. Their presence on paper surfaces can also cause difficulty in sizing, calendering, and printing.

We have found that young material in some clones does not have stone cells. We don't know at what age these clones start forming stone cells. But if clones can be selected that do not form stone cells until after harvest age, then the problem will disappear. Even if selection does not totally eliminate stone cells, young material should have fewer of them than old material because their formation is part of aging.

Although fiber production by maximum yield systems can alleviate the major problems, some new problems, unique to this young material, must be confronted.

One of these problems is bark content. As mentioned earlier we can reduce the deleterious cellular elements found within bark, but total bark content still appears large. Pulp yields and strengths are adversely affected by the predominance of thin-walled cells in bark. Bark comprises 10 percent of conventional pulpwood from many species, but approximately 25 percent of total aerial portions of very young material. The latter figure includes bark on branches and tops as well as on stems while conventional pulpwood figures are only for stem portions.

Bark content can be reduced. As trees become larger, bark contents become proportionately smaller. Growth models of maximum fiber yield plantations indicate an optimum rotation age of 10 to 15 years, and with rapid growth, these trees will be rather large, so the bark percentage should be less than for the small, very young material we have studied. Bark content can also be reduced by plant selection. Anatonical studies of many clones show bark percentage to be variable. Low bark percentage has been a major criterion in our plant selection.

Plant selection will also be extremely helpful in reducing other problems associated with young, rapidly grown material. Reaction wood and branch fiber can cause processing problems. The branch content and incidence of reaction wood appears to be larger in younger trees, and also varies with clones. Again we will make plant selections that diminish these problems. Cultural practices

such as spacing, can also affect branch content within a clone and spacings will be chosen to achieve the best compromise between branch content and yield.

The major objection to material grown in maximum fiber yield systems is that the wood is juvenile. Juvenile wood characteristically has lower cellulose content and shorter fibers than mature wood, which results in lower pulp yield and strength. However, in our studies we are seeking clones that have anatonical, chemical, and physical characteristics more like those of mature wood.

Yet juvenile wood cannot be all bad--all trees contain some juvenile wood! An eminent forestry researcher made the following analogy in explaining problems with pulping juvenile wood: *you can't cook a steak from an old bull with one from a young bull and expect both to be cooked to a "T".* True. But you can cook each individually, under conditions proper for each, and expect both to be better than when cooked together under compromise conditions.

Within the analogy and rebuttal lie the problem and solution of pulping juvenile wood. Juvenile wood is more "tender" than mature wood. When it is cooked under the severe conditions necessary for mature wood, pulp yield and strength must suffer. Yet when cooked alone, under conditions tailored for it, the pulp yield and strength from juvenile wood should improve.

In the future we will see pulp lines and possibly whole plants run solely on rough, juvenile material. We are now mixing rough wood or juvenile chips with clean chips up to proportions at which acceptable products can still be manufactured using existing equipment. The compromises necessary to handle these mixtures hurt efficiency. When proper equipment and conditions are available to handle a uniform raw material, then efficiency should increase.

The greatest attribute of material produced in maximum fiber yield systems is uniformity. Uniformity is gained by minimizing sources of variation within woody materials: genetics, environment, and age.

In maximum fiber yield plantations, we will be planting only a few clones. By definition, all members of a clone are genetically identical; therefore genetic variation is eliminated. The plantations will be fertilized to ensure ample nutrients. They will also be irrigated to provide all the water needed day after day, week after week, and growing season after growing season. Through fertilization and irrigation, the environment will be modified to make it more constant, thereby reducing this source of variation. The anatomical, chemical, and physical characteristics of a tree vary with age. However, the young trees will be harvested before large within-tree variations due to age show up. In addition, all trees within a plantation will be the same age.

In summary, reduced grit and troublesome bark cells along with great uniformity make material produced in maximum fiber yield systems extremely attractive. Once specific machinery and operating conditions are established for this uniform material, maybe the mill employees can then take an extended coffee break. As the chronic fiber shortage becomes more severe, the medicine we offer to cure this illness will be very palatable, and probably habit forming.

PULP AND PAPER CHARACTERISTICS OF POPULUS HYBRIDS

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Intensively cultured Populus *hybrids show promise as future pulpwood species for the pulp and paper industry in the Lake States. Harvesting and processing will be geared to the concept of whole-tree utilization. Research is underway to evaluate the pulp quality of these hybrid species.* Populus *hybrids will be selected for specific end product uses. Such pulps may have unique properties not available in "naturally" growing hardwoods.*

The use of hardwoods by the pulp and paper industry in the Lake States over the past 25 years has increased tremendously; *Populus* species, primarily quaking aspen (*P. tremuloides*) and bigtooth aspen (*P. grandidentata*), now constitute about 48 percent of the total pulpwood production (Blyth 1975). The demand for paper and board will certainly double, and may triple, by the year 2000 (USDA Forest Service 1973). Serious fiber shortages, however, are predicted to occur as early as 1980. Several paper mills in the Lake States already are having problems procuring pulpwood, especiall[y] softwood species. So interest in utilizing hardwood continues to increase.

Whole-tree utilization is one means of increasing and extending the available fiber supply. The harvesting of all aboveground components--tops and branches--in addition to the merchantable bole of northern hardwood doubles the tonnage obtainable per acre compared with conventional harvesting methods (Keays 1975). Whole-tree utilization, however, is but one part of the solution.

Intensively cultured hybrid *Populus* species seem ideally suited for growing the maximum amount of wood fiber per acre per year in the Lake States (Dawson and Hutchinson 1972). Planting short rotation (10 to 15 years) northern plantations on harvested forest land and marginal agricultural land not only will help meet future fiber demands but will also utilize our natural resources more efficiently.

But will these fibers be suitable for manufacturing the various pulp and paper products on the market today? Basic data on the pulp and paper characteristics of these young, fast-growing hybrids are needed so that hybrid species can be selected, improved genetically, or cultured differently to produce fiber "engineered" for a specific end product use.

HARVESTING OPERATIONS

Whole-tree chipping of these *Populus* plantations appears to be the most efficien[t] harvesting method. Whole-tree chipping, as presently practiced, involves feller bunchers, skidders, and mobile chippers. The development of an off-ground chipping method would eliminate much of the sand and grit entering the chip supply. Chip screening, including perhaps some partial

screening in the woods along with additional screening and washing operations at the mill, would upgrade the quality of chips entering the processing system. Further separation to remove the foliage would permit the production of valuable byproducts such as muka, an animal-feed vitamin supplement, and chemicals for the pharmaceutical, cosmetic, and food industries (Keays and Barton 1975).

PROCESSING OPERATIONS

The young trees of short-rotation plantings contain greater percentages of bark due to the higher proportion of tops, branches, and twigs. The bark adheres strongly to these small-diameter components and is difficult to separate from the wood. In the kraft pulping process it is possible to pulp (cook) the bark along with the wood in order to utilize the long-fiber components of the bark. However, the presence of the bark, tops, and branches (and juvenile wood) leads to reduced pulp yields, higher black liquor solids, and greater consumption of pulping chemicals (Wawer 1975). Any decrease in the pulp yield, however, will be more than offset by the increased fiber yield gained from the forest land. Burning the bark, along with the other wood constituents and inorganic pulping chemicals in the black liquor, allows some energy recovery from this resource. If the pulp is bleached, slightly lower yields and somewhat greater consumption of bleaching chemicals also are expected (Ringley 1975). Other pulping processes, such as mechanical pulping, may require bark-chip separation by one of the many methods under development (Fuller 1974).

Existing or future mills should have sufficient digester, recovery boiler, and bleach plant capacity to process these whole-tree chips. But if it does not take as long to cook this juvenile material, pulpmill productivity may be maintained with the existing digester capacity. There have been some reports of effluent problems associated with the use of whole-tree chips. Closed-cycle kraft mills (Rapson 1967), which eliminate external effluent treatments, are one approach to such problems.

PULP QUALITY

Juvenile wood is generally believed to result in weaker pulps. As such, will our young, rapidly grown trees present a problem? We do not believe so because kraft pulp prepared from young (6 year) *Populus* species has been reported to be as strong as that from more mature trees (Hunt and Keays 1973b). Furthermore, the strength properties of some short rotation (10 years) *Populus hybrids* appear to be even superior to those of the mature *Populus* species found in our forests (Einspahr *et al.* 1970). Even though whole-tree chips may contain bark, tops, and branch-wood, which reduce the strength of pulps (Hunt and Keays 1973a), it is not unreasonable to expect that some *Populus* hybrids will produce kraft pulps having competitive (or even superior) strength properties.

PROGRESS TO DATE

The specific objectives of the study underway in our laboratory are (1) to evaluate the potential of the juvenile wood, both with and without bark, from intensively cultured hybrid *Populus* species for use in the manufacture of fine papers and newsprint by the kraft and refiner-mechanical pulping processes, and (2) to determine those changes in the processing variables necessary for producing acceptable fiber products. Unfortunately, the amount of hybrid material available for pulping studies is limited. So, mature quaking aspen is being used not only as a control against which to compare the pulp and paper characteristics of the *Populus* hybrids but also for perfecting techniques and for preliminary pulping studies.

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"AGRICULTURAL" POPLARS AS A RAW MATERIAL FOR STRUCTURAL PARTICLEBOARD

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The bulk harvesting and handling methods associated with agriculture-grown wood may make this raw material an economic reality to the reconstituted board and fiber industries. Research indicates the technical feasibility of using 5- and 6-year-old Populus *hybrids in structural particleboard. With the exception of internal bond retention following an accelerated aging treatment, physical properties were acceptable. Limited data suggest that board properties do respond to changes in anatomical aspects of the raw material.*

By definition, "agriculture wood" can be machine harvested in bulk form using methods similar to those employed in today's typical farming. This differs from the mechanical methods presently used to harvest pulpwood either in natural or plantation stands of timber. The bulk handling of wood chips, flakes, or fiber is of primary economic importance in agriculture-grown wood, and the harvesting machine capabilities well may set the upper limit of the cutting cycle.

Economical production of particleboard has traditionally demanded inexpensive wood as a raw material. In competition with plywood, the higher resin consumption required for particleboard has been offset by cheaper wood and greater manufacuring automation. The relative economic importance of cheap wood can be appreciated by reviewing the history of two particleboard mills here in the Lake States. Both mills, one in Wisconsin and the other in Michigan, were originally designed to use roundwood as a primary source of raw material. Both plants have revised their operations to utilize residues from area mills and now include "whole tree" chipped material in their product.

The utilization of chips has not been without problems. Compromises in homogeneity of furnish, manufacturing methods, and final board properties have been made to take advantage of the cheaper raw material. Although the use of agriculture-grown wood for particleboard has several advantages over wood from natural stands, depending on the final product manufactured, the issue governing the use of such wood for particleboard will be cost.

A specific advantage of agriculture-grown wood over "whole tree" chips is the lower percentage of dirt. Initial particleboard production cost as well as remanufacturing cost is reduced as the silica content decreases. An additional advantage of agriculture-grown wood is that its ready availability would permit carrying a lower "in yard" inventory.

A disadvantage is the high percentage of bark, which normally impairs board physical properties and causes severe finishing problems because of local thickness swelling differentials.

To be economical the bark should be left in the product, so our research was directed towards utilizing the material in a structural board where appearance was not of primary concern. The program dovetailed nicely into our current work on producing structural board from forest residue. A method is being developed to produce "structural" flake material from chips. This involves using fingerling-type chips in a ring-type flaker. The outer drum of a ring flaker contains a series of knives that cut the flakes from chips, which are forced into the knives by a center impeller. Fingerling chips, because of their shape, tend to align themselves with the wood grain parallel to the knives, allowing the production of long flakes with a minimum of fines.

Several machines have been invented or modified to produce fingerlings. Of specific interest is a helical, screw-type shear developed at the North Central Forest Experiment Station's Forest Engineering Laboratory in Houghton, Michigan. This chipper proved to be ideally suited for making fingerlings from 5- and 6-year-old hybrid poplar clones. To gleam the maximum information from the limited supply of material, our research was directed at making several board types with little replication. So, reliability of the data is somewhat questionable.

As mentioned previously, bark generally degrades board properties, especially when used in quantities in excess of 10 percent. Reduction in average fiber length and an increase in adhesive-consuming fines are the major contributing factors. Boards made from 4- to 5-year-old hybrid poplar clones, however, had very good physical properties. Although this material contained 30 percent bark, the fines content of the furnish (that portion passing a 1/32-inch screen) was 5 to 20 percent. The juvenile bark has longer fibers than juvenile wood and therefore may contribute some to the strength of the board.

Boards made from material from which the buds and small twigs were removed had only slightly better physical properties than those boards containing all of the aboveground material except leaves. Elimination of fines (-1/32-inch screen) increased bending properties and internal bond by about 9 percent.

Planting spacing did affect board properties. The 9- by 9- and 12- by 12-inch spaced trees were combined and produced boards 9 percent stiffer and 14 percent stronger in bending than boards made from 24- by 24-inch spaced trees. This comparison was made on the 5261 "Northwest" material only, but did hold true in six different combinations of 4- and 5-year-old material. The superior properties of the closer-spaced material may be attributed to longer fibers.

Because of the replication limitations, it is difficult to accurately determine the effect of age difference on the boards made with 4- and 5-year material. Bending stiffness increased an average of 23 percent and strength an average of 14 percent with the 1 year's growth. However, these gains averaged only 7 percent in boards having the fines removed. The analysis is complicated by the fact that the 4-year-old material had 5 percent fines and the 5-year-old had 15 to 20 percent fines. Removing more fines may have increased the wood-to-bark ratio, which in turn increased strength. Analysis is further complicated by an interaction between plant spacing, removal of fines, and age.

Lineal expansion in 50 to 90 percent relative humidity averaged 0.12 percent while thickness swell was 10.8 percent. The lineal expansion is well within the 0.25 percent allowed by commercial standard 236-66 for higher grade, medium density exterior (type 2B2) particleboard. Retention of properties following accelerated aging tests was better for the 5-year-old group, averaging 71 percent for modulus of elasticity and 100 percent for modulus of rupture based on thickness before test. Springback was high and specific gravity retention averaged 72 percent. Retention of internal bond following accelerated aging was therefore low and is attributed to the high percentage of bark and/or juvenile wood. This property, as expected, responded positively to an increase of resin content.

With the exception of three boards made from 5-year-old *Tristis* 5260, all boards have been made from *Populus Northwest* 5261. We are currently testing boards made from the hybrids, *Northwest* 5261, *Tristis* 5260, *Cranden* 5339, *Populus* spp. 5351, and the *deltoides* clone 5273. Boards are being made to evaluate differences among species in specific gravity, bark versus no bark, flake thickness,

and other factors, including flake alignment pertinent to development of a structural board.

The limited research done so far illustrates the technical feasibility of producing structural particleboard from agriculture-grown *Populus*, and indicates that board properties are responsive to changes in anatomical differences in the raw material. Use of this potential source of fiber for the reconstituted board industry will ultimately depend on the economic environment.

PESTICIDE PRECAUTIONARY STATEMENT

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

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USDA Forest Service.
1976. Intensive plantation culture: five years research. USDA For. Serv. Gen. Tech. Rep. NC-21, 117 p., illus. North Cent. For. Exp. Stn., St. Paul, Minn.

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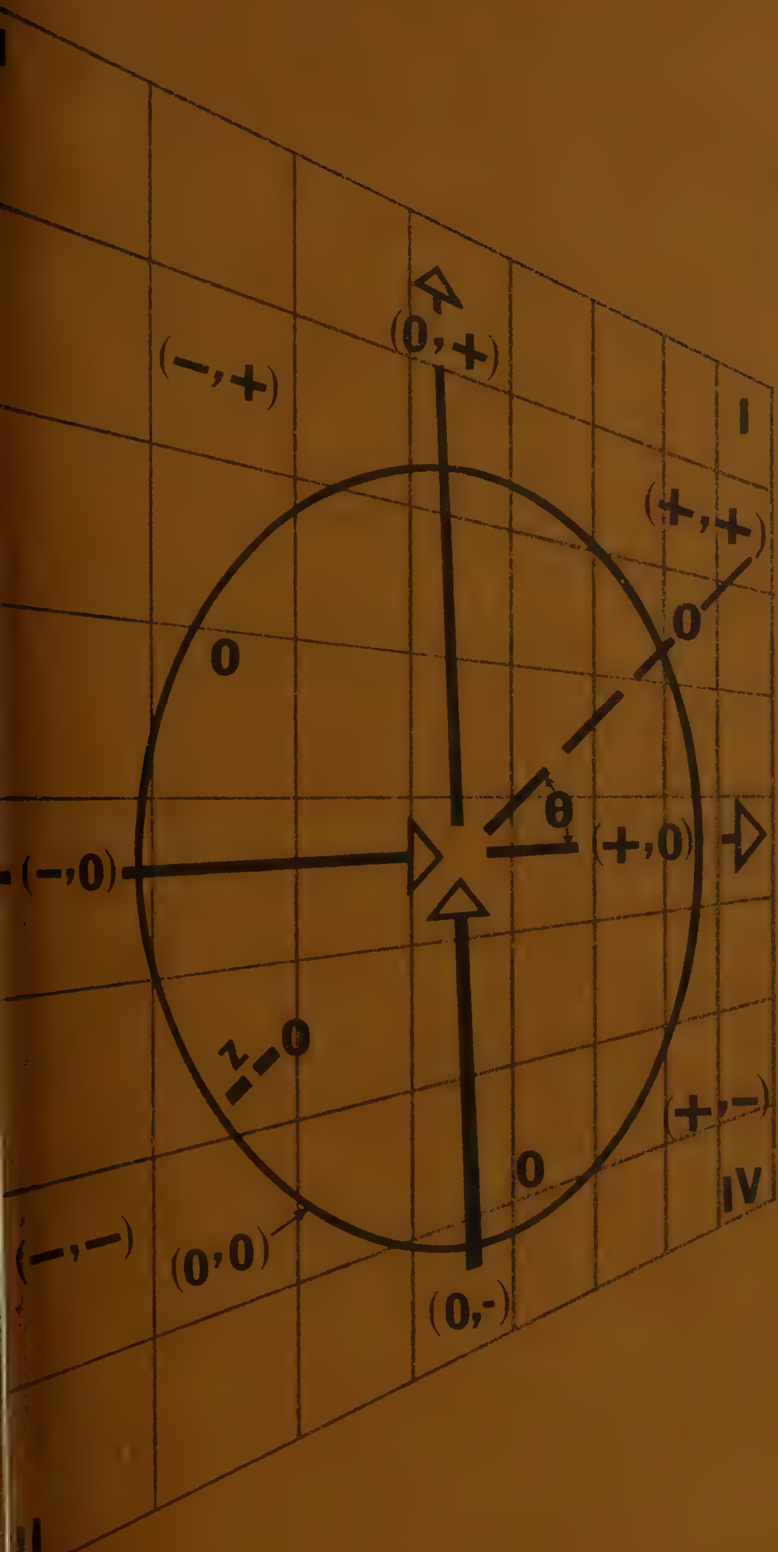

INTERACTION GEOMETRY: AN ECOLOGICAL PERSPECTIVE

BY ROLFE A. LEARY

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REST SERVICE • U.S. DEPARTMENT OF AGRICULTURE

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CONTENTS

Rationale for Coordinate System Form 4
Example of Coordinate System Use 4
The Periodic Coordinate System in Synthesis 7
References 8
Appendix 8

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INTERACTION GEOMETRY: AN ECOLOGICAL PERSPECTIVE[1]

Rolfe A. Leary

The study of interactions has long een an interest of ecologists. Indeed, nteraction is now included in the defini- ion of ecology as a science; e.g., "Ecology s the scientific study of the interactions hich determine the distribution and abun- ance of organisms" (Krebs 1972). It is undamental that studies of biological inter- ctions involve comparisons of entities under wo conditions--roughly, separate and together. he earmark of interacting entities is that hey are different when developing together han when separate (Williamson 1972, Odum 971, Malcolm 1966). Although the experi- ental apparatus used to study interactions re entity-dependent, there has evolved a imited number of mathematical methods for heir analysis. Generally speaking these ay be grouped in two classes--analysis mathematical equations) and geometry (coor- inate systems). Within the geometric class, he only one of concern here, there are two ypes of study, relational and metric.

The relational characterization of in- eractions has been oriented primarily to he coaction cross-tabulation (fig. 1A). t is based on an ordinal sign given by a omparison of process rates for a standard the "separate" condition) and an experimental ituation (the "together" condition). Several uthors use the cross-tabulation, or variations f it, to classify types of interactions and o orient discussions of entity systems that ossess particular types of interactions. his is the coaction cross-tabulation's rimary strength--for broad groupings by ype of interaction. It does not have dis- riminating power within the class and thus functions much as a first approximation, pigeonholing, classification scheme.

The simplest metric method is the time series; a graph of entity attributes plotted over time for the two conditions, separate and together. The method is considered metric because entity attributes are express- ed on a cardinal scale as opposed to the comparative relational scale in the coaction cross-tabulation. Surprisingly, many inter- action studies stop with this step. It is left to the reader to determine the type and intensity of interactions by making appropriate comparisons of entity attributes under the two conditions.

An extension of the time series is the phase plane (fig. 1B). When used to describe several experiments with different (0,0) equilibrium points, the phase plane is pri- marily useful for determining intensity of interaction. The natural grouping of points, (0,0) and $(\overline{0,0})$, in the phase plane is by magnitude of numerical values associated with $(\overline{0,0})$ or (0,0) conditions, not by type of interaction.

Haskell (1970) recently introduced a new coordinate system (fig. 2) that combines the metric (phase plane) and relational (coaction cross-tabulation) methods of studying interactions. It is called the Periodic coordinate system (PCS). This paper is concerned with methods of calcula- tion involved in the rationale and use of this new coordinate system. For a discus- sion of other properties and uses, see Haskell (1972).

The initial steps toward development of the PCS were taken by Haskell in the 1940's. One of the first steps was to con- vert the coaction cross-tabulation into a

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[1]*I thank Edward Haskell and Harold assidy for introducing me to the Periodic oordinate system and Egolfs Bakuzis who alled my attention to Haskell's work.*

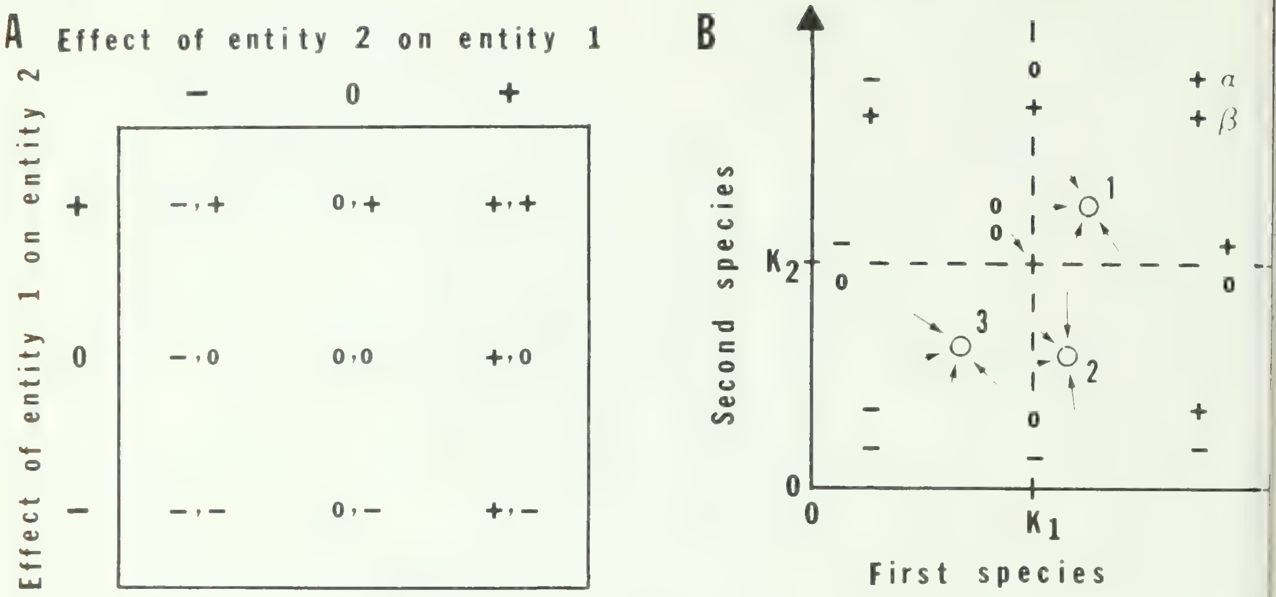

Figure 1.--*(Left.) The coaction cross-tabulation (Haskell 1947). The sign + at the column head indicates that some process rate for entity 1 is greater in the presence of entity 2 than in its absence; - that it is less; 0 that it is the same. The "separate" experimental condition is henceforth called the (0,0) interaction, and the "together" condition, $(\overline{0,0})$. (Right.) Phase plane for analyzing two-species interactions. The point K_1,K_2 represents equilibrium species population attributes when developing separately. The phase space is partitioned into four regions around the point K_1, K_2, four lines and the point itself, using all possible combinations of signs of the coefficients of struggle in the Volterra-Lotka equations. The three small circles represent equilibrium points for interacting species as analyzed by Gause and Witt (1935).*

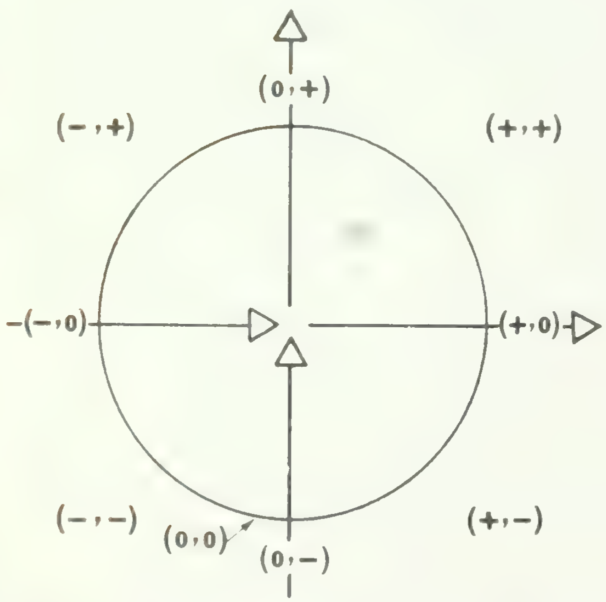

Figure 2.--*The Periodic coordinate system invented by Edward Haskell (Haskell 1970).*

relational coordinate system (RCS) (fig. This was accomplished by making each bi-ordinal relation in the coaction cross-tabulation a quadrant (2-dimensional regi in the coordinate system, each interactio involving one 0 (neutral) effect an axis of the system and the (0,0) interaction the point of convergence of the four axes In retrospect it is apparent that Gause a Witt had done a similar thing.[2] However, theirs was based on coefficients in the Volterra-Lotka equations and they apparen did not consider it to be a coordinate system in its own right; rather, as a bas for partitioning the phase plane.

The second step was to embed the pha plane into the RCS. The method of embedd placed the three separate experiments in figure 1B into figure 3A. Experiment 1 w placed in quadrant I, figure 3A, by placi metric axes on relational axes. Experime

[2]*Personal communication with G. F. Gause, 1974.*

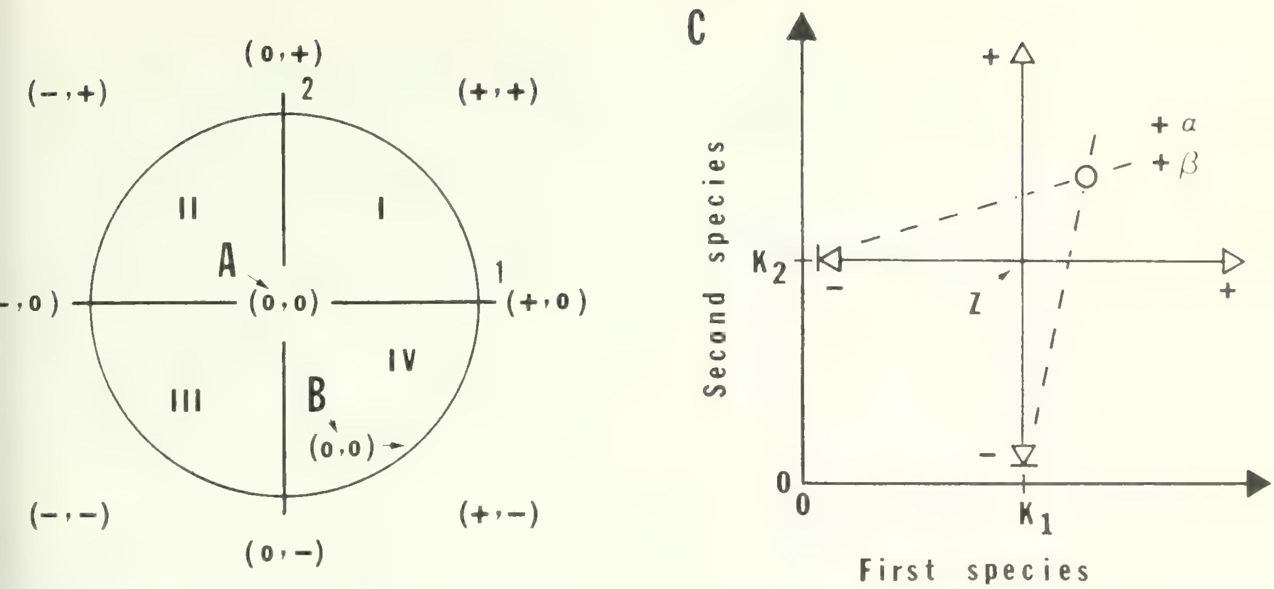

Figure 3.--*(Left.) (A) Relational coordinate system evolved from the coaction cross-tabulation. (Left.) (B) The relational coordinate system with the (0,0) relation represented by a circle rather than a point. The other relations are collectively called $(\overline{0,0})$ interactions. (Right.) . (C) Metric coordinate systems. The absolute axes have solid arrowheads, the relative axes have open heads. There are four relative metric axes; two of increase (+) and two of decrease (-). The relative axes of decrease are of finite length, ending at the appropriate absolute axis. They intersect at the point Z, where α=0=β.*

was placed in quadrant II, figure 3A, me-ric axes on relational axes, after the hor-zontal metric axis had been reflected about he vertical axis. Experiment 3 was placed n quadrant III, figure 3A, but only after eflecting each metric axis about its accom-anying axis. In this way it was seen that he (0,0) relation could be a circle (fig. 3) or a point, depending on the numerical agnitude of the equilibrium values.

The result of this embedding procedure s a coordinate system that has four axes f increase, all directed outward from the enter in the direction of increasing posi-ive numbers (fig. 4). On the other hand, he coordinate system introduced by Haskell 1970) has four relative axes, two of in-rease from the (0,0) circle that are direct- outward and two of decrease from the (0,0) rcle, directed inward (fig. 2). The two jor differences between these two coor-nate systems are the reversed direction two of the axes and the change from four solute axes of increase to two of relative

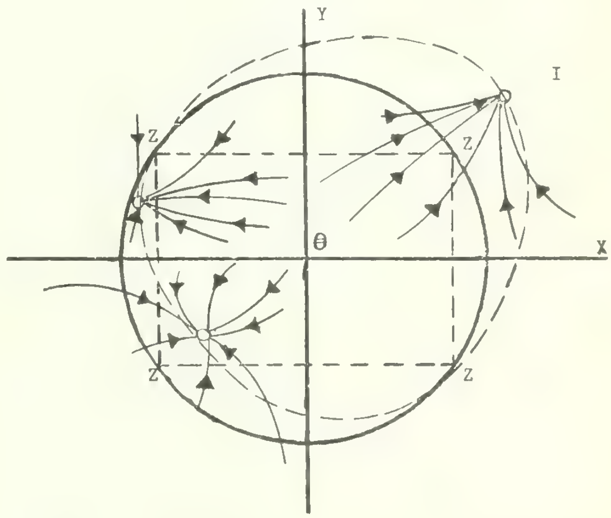

Figure 4.--*Mapping of three Gause and Witt examples (figure 1B) into the relational coordinate system (figure 3A). (From Haskell and Cassidy 1961.) (Reproduced with the permission of Edward Haskell.)*

increase and two of relative decrease. In Part I of this paper I develop an ecological rationale for the type of axes (absolute/ relative) and direction of axes (outward/ inward).

In Part II I present a method of computing that can be used in all quadrants of the PCS (Leary 1972). The need for this is seen as follows:

> ...the method of calculation appropriate to the Cartesian coordinate system does not suffice for the Periodic coordinate system. The methods appropriate to the latter include the former, but go beyond it.--One method, developed by H. G. Cassidy...[is in (Haskell 1972)] ...Another method, which is still incomplete, was developed by Gause and Witt,...However, while their equation works in quadrants 1 and 3, Cassidy and I have not succeeded in adapting it to quadrants 2 and 4 [of the PCS]. (Haskell 1972).

The method of computation is then applied to an illustrative example of coordinate system use on a famous experiment of Gause (1934).[3]

RATIONALE FOR COORDINATE SYSTEM FORM

An alternative method of combining coordinate systems is to embed the phase plane in figure 3C into figure 3B. They have but one property in common: the relation of reciprocal neutrality (0,0) in 3B and Z (α=0=β) in 3C. Thus, an embedding of 3C into 3B begins by bringing into coincidence Z and the (0,0) circle. But where on the (0,0) circle should the Z point be located? A logical rule for placement is shown in figure 5A: Place 3C in 3B so that a radius from the center of 3B connects first the point Z and then the point for the experiment in question (see fig. 1B, points 1, 2, 3).[4]

The examples in quadrants I, III, and IV are from Gause and Witt (1935); the one in II is hypothetical, for purposes of completeness. Notice that all experimenta[l] points are located outside the (0,0) circl[e]. An argument can be made that the region outside the circle should be reserved for enhancing interactions, hence axes of rela[-] tive increase should be directed outside the circle and, contrarily, that relative decrease axes should be directed inside th[e] circle. The argument is based on three co[n-] siderations: (1) that the radius of the (0,0) circle is in some way proportional t[o] the numerical magnitude of K_1 and K_2 (e.g. their sum), (2) the existence of mutual ob[-] ligate enhancing interactions (where K_1,K_2 is numerically 0,0) and, (3) the nonexiste[nce] of mutual obligate negative interactions.

Figure 5A may be simplified by discar[d-] ing the absolute metric axes (solid arrows and the two inward-directed relative metri[c] axes (see fig. 5B, quadrant I). Other ste[ps] produce figure 5B. The final step to the Periodic coordinate system is to notice in figure 5B that each axis of the relational coordinate system separates two similarly directed relative metric axes, and to allo[w] the former to "carry" the latter. This produces the coordinate system, figure 5C, invented by Edward Haskell.

Figure 5C is a construct that combine[s] aspects of both the relational and metric methods of studying interactions. It is a quantification of the coaction cross-tabul[a-] tion long used by ecologists to orient an[d] classify organisms by their type of interaction. The coaction cross-tabulation, o[n] the other hand, is a mathematization (but not quantification) of the concept "interaction" because it is based only on ordin[al] relations (>,<,=). The Periodic coordinat[e] system quantifies the concept but still re[-] tains the ordinal framework.

Inclusion of the relative metric axe[s] in the cross-tabulation allows cardinal specification of type of interaction usin[g] the angle θ, and because of an entirely new dimension it allows quantitative state[-] ments about intensity of interaction (fig[.] 5C). Thus, it appears to combine the cla[ss-] ifying power of the cross-tabulation and the discriminating power of the phase pla[ne].

EXAMPLE OF COORDINATE SYSTEM USE

Use of the Periodic coordinate syste[m] for interaction analysis may be shown in [a] simple example. The experiment is that o[f] Gause (1934).[3]

---

[3] *I analyzed the* Paramecium aurelia *and* P. caudatum *experiments discussed on pages 98 to 103, with experimental data given in Appendix I, Table 3, columns head "mean."*

[4] *Notice that my placement rule puts experiment 2 (fig. 1B) in quadrant IV instead of quadrant II. This is a slight correction in Haskell's mapping.*

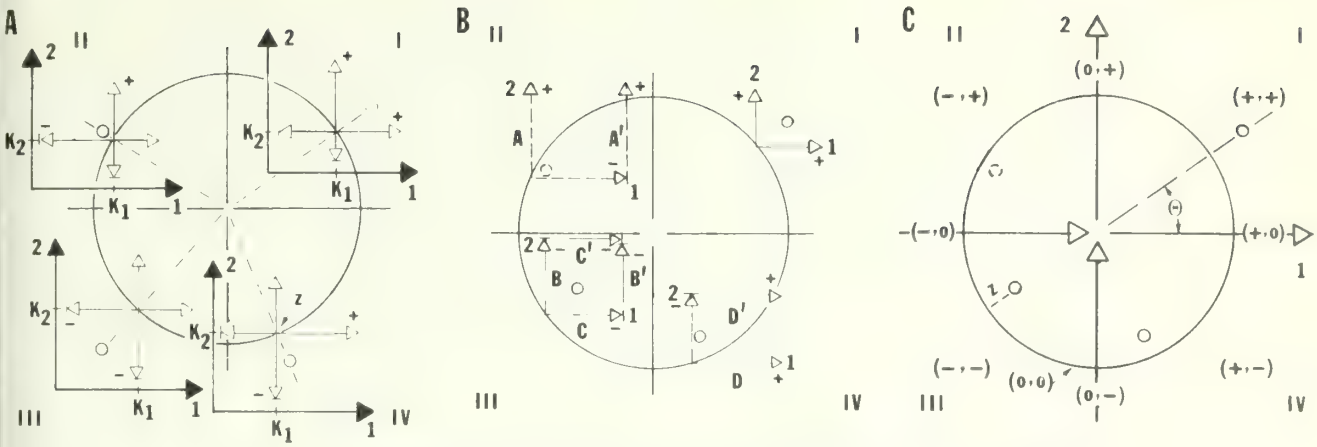

Figure 5.--*(Left.) My method of embedding metric into relational coordinate systems. Placement rules are three: put Z point on (0,0) circle, position so common radius connects Z and experimental points, and maintain conventional directions for Cartesian axes. (Middle.) Intermediate steps in transition from 5A to 5C. Step 1 is to drop both absolute and the two inward directed relative metric axes (see quadrant I). Step two is to reflect each relative axis of decrease about its accompanying axis (necessary once in II and IV, twice in III). Step 3 is to translate axes A,B,C,D to positions A',B',C',D'. (Right.) The Periodic coordinate system produced by allowing each relational axis to "carry" the relative axes it separates in B. Experimental situations are located by their type of interaction (θ) and their intensity (z), given by the distance from the (0,0) circle.*

The first forward difference equation form of the logistic equation was fit to the (0,0) data using a method wherein the (0,0) data are considered boundary conditions in a multi-point boundary-value problem (Leary and Skog 1972). The procedure was adjusted to reflect removal of 1/10th of the population each day except day 1. The r_i and K_i values were r_1 = 0.9701, K_1 = 203.64 (*P. caudatum*), and r_2 = 1.188, K_2 = 535.19 (*P. aurelia*). The Volterra-Lotka equations, modified as suggested by Hutchinson (1947), fit to the $(\overline{0,0})$ data were:

$$\Delta Y1/\Delta t = 0.9701\ Y1 \left[\frac{203.64 - Y1 + (a_{11} e^{+a_{12} Y2} - 0.5) Y2}{203.64} \right] \quad (1)$$

$$\Delta Y2/\Delta t = 1.188\ Y2 \left[\frac{535.19 - Y2 + (a_{21} + a_{22} t) Y1}{535.19} \right]$$

Analysis showed the a_{ij} to have values a_{11} = [illegible].54, a_{12} = -0.0287, a_{21} = 0.1844, a_{22} = -0.2651. The solution of equation (1) at selected times is shown in figure 6A.

The phase plane analysis is shown in figure 6B. This involves a continuous comparison of two trajectories--(0,0) and $(\overline{0,0})$. The comparison is based on a direction (θ) and distance (z) from (0,0) (the standard) to $(\overline{0,0})$. Theta is easily determined. However, a question exists about the appropriate measure of interaction intensity. In terms of figure 6B this means, how does one determine the length of z, the hypotenuse of the right triangle? Cassidy (1972) used the standard Pythagorean measure: $z^2 = x^2 + y^2$. I have used the simple measure $z = |x + y|$ (Leary 1972).[5] There appears to be no a priori reason to prefer one over the other, although as greater experience is gained with the coordinate system there may be clues as to which, including others, is preferred. One clue that would, for example, favor $(x^2 + y^2)^{1/2}$ and $|x + y|$ over $(x^2 + y^2)^{-1/2}$ is a natural tendency for x and y to become small as they approach the same

[5]*The value z (the absolute value of the algebraic sum) has value zero when $x = y = 0$ and when $\pm x = \mp y$.*

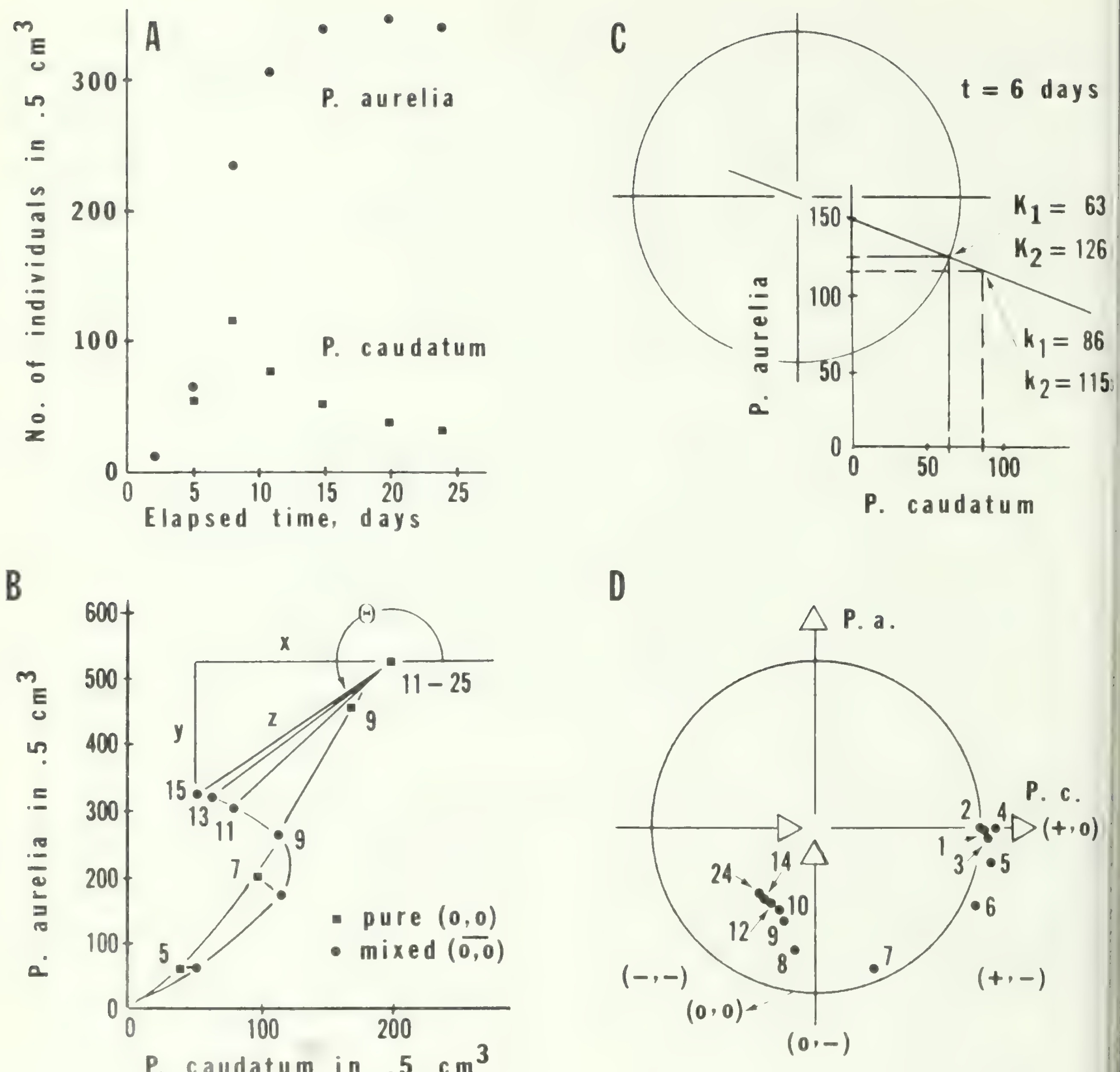

Figure 6.--*(Upper left.) (A) Time series form of Gause experiment*[3] *with mixed population showing predicted values. (Lower left.) (B) Phase plane form of analysis showing that trajectory comparisons form the basis for computing type and intensity of interaction. (Upper right.) (C) Positioning of an observation at day 6 into the relational coordinate system. (Lower right.) (D) Periodic coordinate system representation of Gause experiment.*

absolute value; that is, when gain to one nearly equals loss to another, both gain and loss tend to be small. Of course, $|x + y|$ does not differentiate between situations when $\pm x = \mp y$.

Figure 6C shows the placement of experimental results at day 6, given by solution to my prediction equations, into the relational coordinate system. Table 1 sho[ws] the computations required to determine θ

Table 1.--*Example of interaction computations for analysis of paramecium data of Gause (1934)*[1]

Elapsed time (days)	Pure r_1: P. c.	Pure r_1: P. a.	Mixed r_2: P. c.	Mixed r_2: P. a.	$\theta = \tan^{-1}(\frac{y}{x})$	$z = x + y$	$\frac{\lvert z \rvert}{\lvert r_1 \rvert}$
1	3.9	4.4	4.0	4.4	0°47'	0.073	0.008795
2	7.7	9.5	8.1	9.5	0° 0'	.4	.02326
3	13.3	18.6	15.0	18.5	[2]356°38'	1.7	.05329
4	23.0	35.6	28.2	35.6	0° 0'	5.2	.08874
5	38.7	68.5	52.0	66.2	[3]348°30'	9.3	.08675
6	62.8	126.4	86.0	115.4	[3]335°12'	12.8	.06765
7	96.2	220.2	113.6	178.2	[3]292°30'	-24.6	.07775
8	134.8	346.5	116.1	233.0	260°39'	-132.2	.2747
9	168.9	466.4	102.8	267.0	251°40'	-265.5	.4179
10	189.4	527.3	89.0	289.0	247°09'	-338.7	.4726
12	199.7	539.0	69.0	316.6	239°34'	-353.1	.4780
14	200.3	539.0	56.2	332.2	235°08'	-350.9	.4746
24	200.4	539.0	33.1	341.3	229°45'	-365.0	.4936

[1]Columns 2-5 are the pure and mixed culture coordinates obtained by solving the appropriate difference equation(s). Following Cassidy (1972), the position vectors r_2 and r_1 have two components (X_2, Y_2) and (X_1, Y_1), where X refers to *P. caudatum* and Y to *P. aurelia*. Figure 6B makes clear the meaning of x and y.

[2]The position for time 3 must be corrected by 45' for axis reflection, so θ_c = 357°23'.

[3]The position for time 5 must be corrected by 2°38', so θ_c = 351°8', for time 6 by 12°3', so θ_3 = 347°15', and for time 7 by 5°4', so θ_c = 297°34'

nd z. Because of the reflection of the xis of decrease, an adjustment must be ade to all points in quadrant IV (and II) or correct positioning of the experiment n figure 6D. Appendix I contains the orrection formula. The latter figure shows he pattern of type and intensity of interction that occurred at selected days in he 25-day experiment. Clearly, intensity, iven by z = |x + y|, did not deviate mateially from z = 0 for the first 7 days of ne experiment. However, after day 7, innsity increased abruptly and type changed ss rapidly toward a near equilibrium near ne center of (-,-).

Figure 6D shows how the PCS separates xperimental results by their components of nteraction: type and intensity. It groups nteractions with the same bi-ordinal type .g., (+,-)) into the same quadrant just s the coaction cross-tabulation does. Within each type, however, it differentiates with ngular precision so that questions, for exmple, how close a (+,-) interaction is to ,0), can be answered. The addition of the ase plane to RCS makes this possible. It so brings with it the dimension needed for asuring interaction intensity. This makes ssible two-dimensional groupings of intertions in the quadrants. It also allows assification of interactions by their ajectories in PCS. For example, (+,-) teractions which begin strong and evolve toward weak would have a trajectory directed toward the (0,0) circle. Those that begin weak, strengthen, and then subside would have a different trajectory (Mattson and Addy 1975). In these respects the PCS has discriminating power that the coaction cross-tabulation does not have, plus it retains the grouping (pigeonholing) asset of the cross-tabulation.

THE PERIODIC COORDINATE SYSTEM IN SYNTHESIS

The example illustrates one manner of using the Periodic coordinate system, i.e., for analysis. In an analysis mode, the coordinate axes are labeled with specific entities. Another use of the coordinate system is for synthesis; for assembling large quantities of experimental results into a single coordinate system. In this mode, the axes are not labeled with specific entities and the map symbols, circles in figure 6D, are replaced with symbols that identify the entities that bear the appropriate relation one to another. For example, the "•" for day 7 might be replaced by a symbol combination (Pc,Pa) denoting that *P. caudatum* and *P. aurelia* bear that relation to each other on day 7.

No doubt other uses can be found for this new coordinate system in ecology and other disciplines where interactions are of interest.

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APPENDIX

When an experimental result falls in quadrants II or IV of the RCS, e.g., figure 6C, a correction must be made to the angle θ before the point is located in the PCS. The necessary information for computing this correction is shown in figure 7.

The objective is to find the angle α that is to be added to θ . Consider the triangle formed by the sides r_1, r_2, and w following reflection about the horizontal axis. The angles opposite the sides r_1, r_2, and w are ρ, γ, and α, respectively. The law of sines for the Euclidean plane shows their relation to be

$$\frac{\sin\rho}{r_1} = \frac{\sin\gamma}{r_2} = \frac{\sin\alpha}{w}.$$

In our case we know r_1, r_2, and γ. Thus we can easily determine ρ and, knowing γ and ρ, also determine α.

Clearly,

$$\rho = \arcsin\left[\frac{r_1 \sin\gamma}{r_2}\right]$$

where $\gamma = \pi - 2\arctan(y/x)$, or $\pi - 2\kappa$. Thus, α is given by

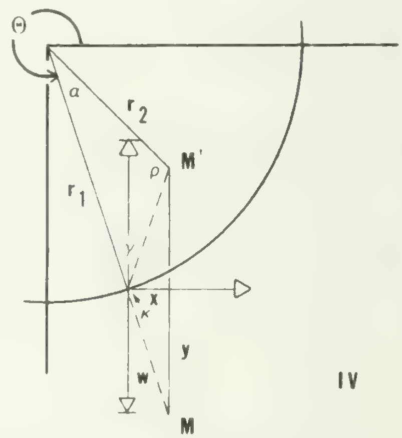

Figure 7.--*Details for locating the position of experimental situation M in quadrant IV before (M) and after (M') correction for reflection of the axis of decrease.*

$$\alpha = \pi - \left[\pi - 2\kappa + \arcsin\left[\frac{r_1 \sin\gamma}{r_2}\right]\right]$$

Note that w is not used in determining the correction angle. Thus, the correction angle determination is not confounded with the question of the geometry of interaction space.

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Leary, Rolfe A.
1976. Interaction geometry: an ecological perspective. USDA For. Serv. Gen. Tech. Rep. NC-22, 8 p., illus. North Cent. For. Exp. Stn., St. Paul, Minn.

A new mathematical coordinate system results from a unique combination of two frameworks long used by ecologists: the phase plane and coaction cross-tabulation. The resulting construct combines the classifying power of the cross-tabulation and discriminating power of the phase plane. It may be used for analysis and synthesis.

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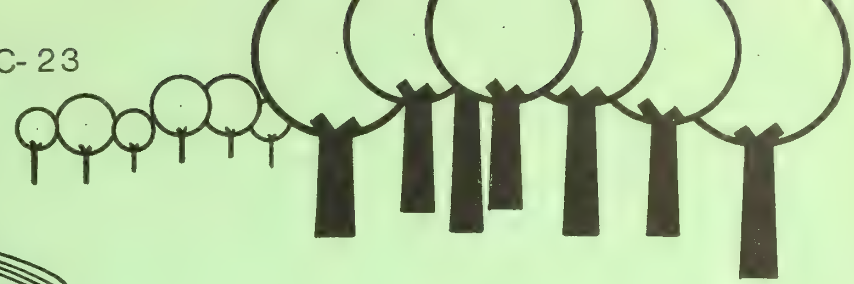

A GUIDE FOR EVALUATING THE ADEQUACY OF OAK ADVANCE REPRODUCTION

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CONTENTS

APPLICATION
To Use This Guide 1
DOCUMENTATION
Background 4
Establishing a Future Stocking Goal 5
Minimum Size Requirements for Oak Advance Reproduction 5
Minimum Number of Oak Advance Reproduction Required 5
Sample Plot Size and Number 6
Numbers of Stump Sprouts Required to Compensate for Deficiencies in Stocking of Oak Advance Reproduction 6
Conclusion 6
Literature Cited 6

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WHAT DO YOU THINK?

Realizing that the needs and interests of our two major "clients"--the scientist and the practitioner--are different, we have been concerned whether our publications have been in a form and style equally useful to both. So we have decided to try a new format for some of our publications, one that might serve this dual purpose better.

The paper is divided into two separate parts: Application and Documentation. The Application section is specifically intended for the man on the ground or in the mill who has a particular job to do or problem to solve. This section describes briefly the situation and the problem, and then goes immediately to the solution, emphasizing the how-to-do-it aspect. It is a complete story in itself; the busy manager need read no further.

The Documentation section describes the details of the research process. It is for the reader interested in laboratory and field procedures, tabulations, statistical analysis, and philosophical discussion. This section, too, is self-contained.

Our purpose is to separate the practical aspects of our research results from the strictly academic ones yet still make both available to all readers. If the practitioner wants to find out how we arrived at our recommendations, the details are in the Documentation section for him to examine. If the scientist has a practical bent, he can turn to the Application section and see the results in action.

It is for you to decide whether we have created a well-matched team or a two-headed monster. We would like to have your opinion.

A GUIDE FOR EVALUATING THE ADEQUACY OF OAK ADVANCE REPRODUCTION

Ivan L. Sander, Paul S. Johnson, and Richard F. Watt

APPLICATION

The purpose of this guide is to enable the user to determine in advance of harvest whether reproduction is adequate to reasonably ensure the regeneration of an oak stand. The guide is based on studies of survival and growth of oak reproduction on a range of sites from site index 50 to 75 for black oak.[1] The guide assumes oaks will be grown in even-aged stands and that the final harvest cutting will completely remove the overstory.

The guide requires inventories of (a) the overstory and (b) the oak advance reproduction. Both inventories should be made at the same time and tallied on a form like figure 1. If the oak advance reproduction inventory shows there are insufficient oaks to replace the stand, the overstory inventory is used to determine whether or not stump sprouts from overstory oaks are likely to be numerous enough to make up the deficiencies in advance reproduction. The inventory routinely used in silvicultural stand examinations to estimate overstory basal area and number of trees per acre will satisfy the requirements for (a) above if all oaks 1.6 inches d.b.h. and larger are included in the number of trees per acre (Roach and Gingrich 1968).

TO USE THIS GUIDE

1. Take 10 or more 10-factor angle gauge sample points in the stand being examined. At each sample point tally the trees on a 1/20-acre plot by species and size class (overstory inventory, see sample form, figure 1).

2. Select the number of 1/735-acre plots (4.3 feet in radius) to use in the advance reproduction inventory from the following tabulation according to the acreage of the stand being examined:

For stand size (acres)	*Use this number of 1/735-acre plots*
<10	25
10-30	40
30-50	60

3. Distribute these 1/735-acre plots uniformly throughout the stand.

4. On each 1/735-acre plot look for oak reproduction stems 4.5 feet tall or taller and less than 2.0 inches in diameter at the ground line or not over 1.5 inches d.b.h. (stems larger than this should be considered part of the overstory and tallied as such, even if below the main canopy). If at least one such stem is present, record the plot as stocked. If no such stem is present, record the plot as not stocked (see right margin of sample form, figure 1).

5. Compute the percent of plots stocked. If 59 percent or more are stocked, there is adequate oak advance reproduction present; no further calculations are necessary and the stand may be harvested.

6. If fewer than 59 percent of the plots are stocked, oak advance reproduction is inadequate to reproduce the stand if it is cut. But the stand could still be reproduced if enough stumps of the overstory oak trees will sprout after they are cut. An example of how to compute the expected number of stump sprouts follows:

   a. Assume that the inventory of plots provides the data on the sample worksheet (fig. 1).

---

[1] *Caution is advised in using this guide in stands having a site index above 70 feet, where there is often a great abundance of fast-growing nonoak competitors. On these good sites the minimum size of advance oak reproduction may need to be larger than that used in this guide.*

Sample point number	Dbh class	Black oak	White oak	Scarlet oak	North. red oak	Chest. oak	Other spp.	Total
1	2-5							
	6-11							
	12-16							
	17+							
2	2-5							
	6-11							
	12-16							
	17+							
3	2-5							
	6-11							
	12-16							
	17+							
4	2-5							
	6-11							
	12-16							
	17+							
5	2-5							
	6-11							
	12-16							
	17+							
6	2-5							
	6-11							
	12-16							
	17+							
7	2-5							
	6-11							
	12-16							
	17+							
8	2-5							
	6-11							
	12-16							
	17+							
9	2-5							
	6-11							
	12-16							
	17+							
10	2-5							
	6-11							
	12-16							
	17+							
Total No. per acre	2-5	26	60	24	4		26	140
	6-11	8	12	2	4		22	48
	12-16	18	8	4	2		14	46
	17+	2	2	0	2		0	6
	Total	54	82	30	12		62	240
No. of stump spts per acre	2-5	22	48	24	4			Total per acre
	6-11	5	6	2	2			
	12-16	4	1	2	1			
	17+	0	0	0	1			
	Total	31	55	28	8			122

Date ____________

Compartment 1

Stand 1

1/735-acre plots

Total No. 40

Stocked ⊠ ⊓

Net Stocked ⊠ ⊠ :·

Percent Stocked 43

Adv. Repro. Adequate no

Adv. Repro. + stump sprouts Adequate YES

Figure 1.--*Example tally form for recording overstory trees, oak advance reproduction stocking, and for computing the number of expected oak stump sprouts. The tally was made on 1/20-acre plots.*

b. Note that there are 26 black oaks 2 to 5 inches in diameter per acre. Multiply 26 by 0.85 (from table 1) to find how many of the 26 stumps would be expected to sprout. 26 x 0.85 = 22. Note that 22, number of expected stump sprouts per acre for 2- to 5-inch black oaks, is listed at the bottom of figure 1.

c. Similarly, compute the expected number of stump sprouts for the other size classes of black oak (5 for the 6- to 11-inch class, 4 for the 12- to 16-inch class, and 0 for the 17+-inch class) and note that all these classes sum to 31. Do the same for all oak species.

d. Summing all oak species and all size classes gives a total of 122 expected stump sprouts per acre (fig. 1).

7. Note that the sample data from figure 1 gave 17 plots stocked of a total of 40, or 43 percent of plots stocked (determined under point 4 above). Go to the tabulation below and find the number of stump sprouts required in combination with stocked plots to meet minimum stocking requirements at the next lowest percent down from 43 (i.e., 40). Opposite 40 note that 97 stump sprouts are needed to make up the deficiency in advance reproduction.

Stocked 1/735-acre plots (Percent[2])	*Stump sprouts required* (Number per acre)
59	0
55	21
50	46
45	71
40	97
35	122
30	147
25	172
20	198
15	223
10	248

8. Because the computed value (122) exceeds the tabulation value (97), there will be enough oak stump sprouts to make up the advance reproduction deficiency. Thus, the oak component of the new stand will be adequate and the old stand can be harvested.

9. If the number of expected stump sprouts does not compensate for advance reproduction deficiencies, harvesting should be delayed until adequate oak advance reproduction is established and reaches the minimum size of 4.5 feet in height.

10. Unless the stand is protected or the wildlife controlled, it will probably be impossible to get adequate natural oak reproduction in areas where deer browsing is heavy and where there are high populations of acorn-consuming wildlife. The alternative is to plant oak seedlings and protect them from wildlife.

[2] *If the percent of stocked plots lies between the 5-percent intervals, use the lower figure, e.g., 43 percent stocked plots should be considered 40 percent.*

DOCUMENTATION

BACKGROUND

Oak Advance Reproduction

It is firmly established that the oak component of new stands following harvest cutting depends on size, number, and distribution of the oak advance reproduction (Sander 1971, 1972; Sander and Clark 1971). However, oak advance reproduction varies greatly under mature or nearly mature stands throughout the oak range in the eastern United States, even within small areas. For example, in West Virginia, a range of 25 to more than 55,000 oaks per acre was reported (Tryon and Carvell 1958). Numbers ranged from about 2,000 to 5,000 trees per acre in Ohio, while in Indiana only 230 per acre were found (Sander and Clark 1971). In Missouri, the number of oaks varied from about 300 to 2,000 per acre.[3] Some of this reported variation is attributable to site quality; in general, oak advance reproduction is more abundant on average and poor sites than on good sites (Arend and Gysel 1952, Carvell and Tryon 1961, Phillips 1963, Sander and Clark 1971).

The abundance of oak advance reproduction alone is not a good indicator of whether or not oaks will be a major component of a new stand after harvest cutting. For example, in southwestern Wisconsin, 900 to 4,000 advance oaks per acre were judged to be inadequate because they were too small to successfully compete with associated vegetation (Arend and Scholz 1969). Thus, tree size as well as tree numbers must be considered.

Oak advance reproduction exists as either true seedlings or sprouts. The root systems of sprout advance reproduction are usually considerably older than the stems, are relatively large, and are capable of supporting much greater stem growth than those of true seedlings. For example, in 12-year-old stands that developed after clearcutting in Illinois, stems from true seedlings averaged less than 2 feet tall and all were suppressed; stems from sprout advance reproduction less than 4.5 feet tall averaged 14 feet and 6 percent were codominant or larger; and stems from advance reproduction over 4.5 feet tall averaged 23 feet tall and 63 percent were codominant or larger (Sander 1972).

Similar height growth patterns were found in a Missouri study where 10 years after clearcutting true seedlings planted at the time of cutting averaged 2 feet tall (McQuilkin 1975). All sprouts from advance reproduction averaged 16 feet tall. However, of the advance sprouts over 3 feet tall, 50 percent attained a height of 19 feet or more; of the advance reproduction 1 to 3 feet tall, only 14 percent attained this height.

In Ohio, growth of new oak sprouts that developed after cutting advance reproduction stems was related to the diameter of the old stem at the ground line (Sander 1971). Three years after cutting, the largest advance reproduction stems produced the fastest growing sprouts, and unless the old stem diameters were at least 0.5 inch, few new sprouts became codominant or larger. Seven-year measurements showed that oak advance reproduction must be larger than 0.6-inch diameter at the ground line before a significant proportion (more than 60 percent) of the new sprouts originating from it will be dominant or codominant.[3] Thus tree diameter or height can be used as an indicator of total plant size and the potential of the root systems to support vigorous shoot growth after the overstory is removed.

The Role of Stump Sprouts

Stump sprouts should also be considered when evaluating potential oak regeneration before clearcutting because they are the most rapidly growing oak component of new stands. For example, 5-year-old white, black, scarlet, northern red, and chestnut oak stump sprouts in Virginia averaged more than 10 feet in height (Roth and Hepting 1943). In Missouri the average height of oak stump sprouts at age 5 for white, black, and scarlet oak was over 12 feet, and 83 percent of them were at least 10 feet tall.[3] Although tree crown class was not determined in these studies, trees that can attain a height of 10 feet at age 5 are assured a position of codominance or better.

Although decay in stump sprouts has sometimes been of concern, oak sprouts originating at or below ground level have a low probability of becoming infected via the

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[3] *Unpublished data, North Central Forest Experiment Station, Columbia, Missouri.*

arent stump (Roth and Hepting 1969). However, if many sprouts persist on a single stump, they may develop sweep in the lower portion of the bole. This can be avoided if lumps are thinned in early cleanings.

The oak species vary considerably in heir capacity to produce stump sprouts. lthough several factors influence stump prouting, stump diameter is most often nd most easily related to the proportion f stumps that sprout. In general, a larger roportion of small stumps sprout than do arge stumps (Rogers and Rogers 1959, Spaeth 928, Roth and Hepting 1943, Johnson 1975, endel 1975). The data in table 1 were ompiled from several of the sources cited bove and are thus reasonably representative f the eastern oak forest.

able 1.--*Expected percentage of oak stumps that will sprout after cutting*[1]

Size class [2] (inches)	Black oak	Scarlet oak	Northern red oak	White oak	Chestnut oak
2-5	85	100	100	80	100
6-11	65	85	60	50	90
12-16	20	50	45	15	75
17+	5	20	30	0	50

[1] Adapted from Roth and Hepting (1943), Wendel (1975), Johnson (1975), and unpublished data at Columbia, Missouri.

[2] D.b.h. class of parent tree.

ESTABLISHING A FUTURE STOCKING GOAL

The determination of the minimum amount oak advance reproduction for adequate tocking in a new stand requires first defining "adequate stocking." At some future tage of stand development there must be nough dominant and codominant oaks in the tand to furnish some minimum stocking level. he stage chosen for this guide is when the ean stand diameter is 3 inches--the lowest ean stand diameter shown on Gingrich's 967) stocking chart. The goal is to have he stand 30 percent stocked with codominant d dominant oaks at this mean stand iameter. Total stand stocking will higher because trees of other species d probably some smaller oaks will be preent.

A study in Missouri showed that unmanaged k stands reached a mean stand diameter of inches at age 20 to 25, and the dominant d codominant trees average 4.5 inches in diameter.[4] According to Gingrich's (1967) equation for defining minimum tree area requirements, one 4.5-inch tree contributes 0.136 percent stocking. To meet the goal of 30 percent stocking then requires 30 ÷ 0.136 or 221 codominant or larger trees averaging 4.5 inches in diameter when the mean stand diameter is 3 inches.

MINIMUM SIZE REQUIREMENTS FOR OAK ADVANCE REPRODUCTION

Data from an Illinois study were used to ascertain the average survival and growth potential of six different classes of oak advance reproduction (Sander 1972). The study, which included black, white, scarlet, and northern red oaks, documented the growth and survival of more than 1,200 trees developing over a 12-year period in clearcuttings. From this data base, oak advance reproduction with a minimum height of 4.5 feet was identified as the only class that would significantly contribute to future acceptable growing stock. Sixty-three percent of the advance reproduction of the minimum size attained dominance or codominance after 12 years. To facilitate calculation of stocking needs, this value was adjusted for anticipated mortality to stand age 20 by assuming a mortality rate of 1 percent per year.[5] Based on this adjustment, 51 percent of oak advance reproduction 4.5 feet tall or taller would be expected to attain a position of dominance or codominance at a mean stand diameter of 3 inches.

MINIMUM NUMBER OF OAK ADVANCE REPRODUCTION REQUIRED

The minimum number of oaks 4.5 feet tall or taller in the advance reproduction (NAR) required to reasonably ensure the future stocking goal of at least 221 dominant and codominant oaks when average stand diameter is 3 inches can be calculated by the formula:

$$NAR = 221/0.51 = 433 \quad \text{(Eq. 1)}$$

where 221 = the minimum number of dominant and codominant oaks needed for minimum

[4] *Based on 36 plots in an oak stand density study.*

[5] *This is the average annual mortality rate for the first 12 years of stand development.*

acceptable stocking at a mean stand d.b.h. of 3 inches and 0.51 = the expected proportion of oak advance reproduction 4.5 feet tall or taller which will be codominant or larger at a future mean stand diameter of 3 inches. These 433 trees should be well-distributed.

SAMPLE PLOT SIZE AND NUMBER

The appropriate unit for sampling oak advance reproduction should be related to the average size (4.5 inches d.b.h.) of dominant and codominant trees when the mean stand diameter is 3 inches. Solving Gingrich's (1967) minimum tree area equation reveals that a 4.5-inch tree requires 1.36 milacres of tree area or 1/735 acre of growing space. Theoretically, then, on any given acre the opportunity exists for each 1/735 acre to contain one 4.5-inch tree. Thus the appropriate plot size is 1/735 acre (4.3 feet radius). At or beyond a mean stand diameter of 3 inches, more than one codominant or larger tree would not be expected to persist within this sample space.

There is little experience or data on which to base the number of 1/735-acre plots required to adequately sample advance reproduction; the number of plots listed in the tabulation (point 2, application section) is only a reasonable estimate of the minimum needed. If greater precision is required, a preliminary sample can be used to estimate confidence limits and the required number of plots for a given level of precision based on the binomial distribution can be calculated (Freese 1962).

NUMBERS OF STUMP SPROUTS REQUIRED TO COMPENSATE FOR DEFICIENCIES IN STOCKING OF OAK ADVANCE REPRODUCTION

Data from a Missouri study on oak stump sprouting were used to determine the proportion of stump sprouts that were 10 feet tall (approximately codominant or larger) after five growing seasons. The study, which included white, black, and scarlet oaks, showed 83 percent of stump sprouts attained or exceeded this size. To facilitate calculation of stocking needs, this value was adjusted for anticipated mortality to stand age 20 by assuming a mortality rate of 0.75 percent per year.[6] Based on this adjustment, 74 percent of oak stump sprouts would be expected to occupy a position of dominance or codominance at a mean stand diameter of 3 inches.

The number of stump sprouts per acre (N) needed to make up deficits in advance reproduction stocking was then computed as follows:

$$N = \frac{221 - (0.51(735 \times P))}{0.74} \quad \text{(Eq. 2)}$$

where 221 and 0.51 are defined as in Equation 1; 735 = the maximum number of 1/735-acre plots in 1 acre; P = the proportion of 1/735-acre sample plots which is stocked with at least one oak 4.5 feet tall or taller; and 0.74 = the expected proportion of oak stump sprouts that will be codominant or larger at a mean stand d.b.h. of 3 inches. If P is expressed as *percent* of stocked 1/735-acre plots, Equation 2 can be reduced to:

$$N = 299 - 5.06P. \quad \text{(Eq. 3)}$$

CONCLUSION

This is a preliminary guide because the best information presently available is still incomplete. We hope silviculturists will apply the guide conscientiously, and at periodic intervals after harvest cutting, test its validity by inventorying reproduction. We hope users will share their results with us. Only in this way can we be aware of the guide's shortcomings or strengths and what revisions are needed. It will be revised as experience in application and new information dictates.

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MATHEMATICAL FUNCTIONS FOR PREDICTING GROWTH AND YIELD OF BLACK WALNUT PLANTATIONS IN THE CENTRAL STATES

RAYMOND S. FERELL AND ALLEN L. LUNDGREN

RTH CENTRAL FOREST EXPERIMENT STATION
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CONTENTS

The Model 1
Procedure 2
Results 2
Conclusions 4
Literature Cited 5
Appendix 5

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1976

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MATHEMATICAL FUNCTIONS FOR PREDICTING GROWTH AND YIELD OF BLACK WALNUT PLANTATIONS IN THE CENTRAL STATES

Raymond S. Ferell and Allen L. Lundgren

Probably no other single species has stimulated more interest in growing trees for profit than has black walnut. The expectation of high returns on investment, the sheer beauty of the wood, and the mystique that seems to be associated with products from the wood have generated great interest in planting, growing, and selling the species. At the same time, however, not enough is known about the costs and returns from growing and selling walnut to provide the potential investor with the information necessary to make sound decisions.

As a minimum, the landowner needs to be able to estimate what costs will be incurred, what quantity of products he can get and when, and at what price he will be able to sell his product in order to evaluate return to his investment. To do this he will need a model that will predict the yield of walnut at different ages and under several different conditions. Such a model should be adaptable to computer simulation.

Several studies estimating the potential returns from a plantation investment in growing black walnut have been made (Ferell and Bentley 1969, Callahan and Smith 1974). These have been generally limited to a few alternatives and conditions. Growth and yield data for black walnut are also available from many sources (Funk 1966, Dillow and Baker 1971). This information is generally descriptive in nature and also applicable only to a narrow set of alternatives.

L. F. Kellogg (1940), in an unpublished report of the Central States Forest Experiment Station of the USDA Forest Service, summarized an extensive analysis of data collected in 1928, 1929, and 1930 from more than 200 black walnut plantations, located primarily in Iowa, Illinois, and Indiana. The plantations were well stocked and essentially undisturbed. These data, although old, are the most comprehensive available, covering a wide range of site and stand conditions. In Kellogg's data base, site index (at 50 years) ranged from 40 to 80; stand age from 10 to 75 years; initial stocking from 436 to 4,480 trees per acre (square spacing from 10 feet by 10 feet to 3 feet by 3 feet); surviving number of trees per acre from 119 to 966; total height from 18 to 82 feet; and d.b.h. from 1 to 23 inches. Unfortunately, the original data were not available--only the graphed and tabularized summaries that had already been smoothed and harmonized.

Kellogg derived regression equations for basal area, number of trees, and cubic foot volume per acre as a function of original spacing, site index, and age (Appendix). Tree heights were estimated from site index curves prepared for the plots. Board foot volumes were derived from board foot-cubic foot ratios for average stand diameters. These and other data are presented in tables in his report.

In order to develop a more generalized model better suited for use in computer simulation, new equations were fitted to the tabularized data in the report. This paper presents the results of this work.

THE MODEL

The volume per acre at any plantation age can be determined by multiplying the average volume per tree of average diameter at that age times the number of trees per acre at that age. Volumes are expressed in both cubic feet and in board feet.

Two general equation forms (Lundgren and Dolid 1970) were used to represent tree volumes as a function of average stand height and diameter:

(1) a monomolecular equation of the form

$$V=H(b_1+b_2e^{b_3D}),$$ and

(2) an exponential-monomolecular equation of the form

$$V=b_1H(1.0-e^{b_2D})^{b_3}$$

where:

- V = volume per tree in cubic feet or board feet
- H = total height in feet of dominant and codominant trees
- D = average diameter breast height outside bark, in inches, of a tree
- b_1, b_2, b_3 = parameters to be estimated
- e = base of natural logarithms.

The monomolecular equation is a simpler form that has no point of inflection, whereas the exponential-monomolecular function has the more general S-shape associated with many biological growth functions. To use either function it is necessary to know or to estimate tree height and diameter.

The same two equation forms were used to estimate total height:

$$(1)\quad H=S(b_1+b_2e^{b_3A})$$

$$(2)\quad H=b_1S(1.0-e^{b_2A})^{b_3}$$

where:

- S = site index (total height in feet at tree age 50)
- A = age of tree in years.

The following equation form was fitted to the tree diameter data:

$$D=b_1S(1.0-b_2e^{b_3A+b_4S})e^{b_5T+b_6S}$$

where:

- T = number of trees per acre at age A
- $b_1 \ldots b_6$ = parameters to be estimated.

The number of trees surviving at any age was estimated by the following general form:

$$T=(b_1No/(1.0-e^{b_2S}))e^{b_3A\ No}$$

where:

- T = number of surviving trees per acre at specified age
- No = initial number of trees per acre at time of plantation establishment.

With the above equations and knowing the site index and initial number of trees per acre, one can estimate the surviving number of trees per acre. Using this estimated number of trees per acre, the site index, and age, one can estimate the average stand diameter and height for any age. From this diameter and height one can estimate stand timber volumes per acre at that same age. This, then, is the basic timber yield model derived from Kellogg's data.

PROCEDURE

The specified mathematical functions were fitted to the data given by Kellogg (1940) by the NONLIN program, a modification of the nonlinear regression program of Marquardt (1964). The form of the function and an initial estimate of the parameters is specified. The program, through successive approximations, estimates the parameters using a least squares approach. The program also gives the value of the standard error.

RESULTS

Volume

Most black walnut is sold by board-foot volume measured by the Doyle log rule, but parameters for other board-foot rules and also cubic-foot volume were also estimated (tables 1-3).

For board-foot volume by the Doyle rule, the equation based on the monomolecular function (table 2) is:

$$V=(H)(-1.1705+0.5241\ e^{0.1037\ D}).$$

A tree 80 feet in height and 20 inches in diameter would have a volume of:

$$V=(80)(-1.1705+0.5241\ e^{0.1037(20)})$$

$$V=240.0 \text{ board feet.}$$

Using the exponential-monomolecular function (table 3), we would estimate the volume of the same tree to be:

$$V=26.5436(80)(1.0-e^{-0.05153(20)})^{4.8977}$$

$$V=244.6 \text{ board feet (Doyle).}$$

Both functions give reasonably close estimates within the range of the data. For extrapolations, the exponential-monomolecular function is more reasonable.

Total Height

The total height of the dominant and codominant trees on a site is one of the more commonly used measures of site potential and is required to estimate volumes. The

Table 1.--*Major assumptions used for determining volume by different rules for black walnut timber*

Volume measurement	Stump height	Top diameter	Log length	Trim allowance	Notes
	Feet	*Inches*	*Feet*	*Feet*	
Total cubic feet	1.0	--	--	--	Volume measured by planimeter
Merchantable cubic feet	1.0	4.0	4.0	--	Volume measured by planimeter
Board-foot volume:					
International ¼ inch	1.0	5.0	12.0	0.3	
Scribner (10 inch)	1.0	10.0	12.0	.3	
Scribner (8 inch)	1.0	8.0	12.0	.3	
Doyle[1]	1.0	5.0	12.0	.3	

[1]Converted from International ¼ inch using factors from Forestry Handbook, page 1.59 (Forbes 1956).

Table 2.--*Parameters of the monomolecular functions describing the volume of black walnut trees reported by Kellogg (1940)*[1]

Predicted variable	Standard error	Maximum error[2]	Parameters		
			b_1	b_2	b_3
Merchantable cubic foot volume	0.319	1.0	-0.41937	0.31843	0.07272
Total cubic foot volume	.889	3.6	-.31916	.26255	.07727
Board-foot volume:					
Scribner (10 inch)	3.53	9.9	12.7368	-19.4986	-.03600
Scribner (8 inch)	2.61	7.4	-4.6526	3.0437	.04784
International ¼ inch (5 inch)	8.47	22.1	-2.4654	1.6250	.06935
Doyle	6.13	18.6	-1.1705	.5241	.10370

[1]$V = H(b_1 + b_2 e^{b_3 D})$.
[2]Maximum difference between observed and predicted values over the range of the data.

Table 3.--*Parameters of the exponential-monomolecular functions describing the volume of black walnut trees reported by Kellogg (1940)*[1]

Predicted variable	Standard error	Maximum error[2]	Parameters		
			b_1	b_2	b_3
Merchantable cubic foot volume	0.459	1.9	162.9683	-0.004488	2.0966
Total cubic foot volume	.845	2.7	192.3086	- .003543	1.9939
Board-foot volume:					
Scribner (10 inch)	5.16	13.5	5.4778	- .20283	29.1136
Scribner (8 inch)	4.24	10.9	11.0799	- .08552	6.0640
International ¼ inch (5 inch)	8.62	23.9	47.1558	- .02869	2.9549
Doyle	5.71	16.8	26.5436	- .05153	4.8977

[1]$V = b_1 H(1.0 - e^{b_2 D})^{b_3}$.
[2]Maximum difference between observed and predicted values over the range of the data.

relation of height (H) to age (A), for a known site index (S) was determined using the two equation forms discussed earlier.

For the simpler monomolecular function, the height equation is:

$$H=S(1.2582-1.2027e^{-0.0308A}).$$

For this function the standard error = 0.5284 feet; and the maximum error (the maximum difference between observed and predicted data over the range of data) = 1.1 feet.

For the exponential-monomolecular function, the height equation is:

$$H=1.2756(S)(1.0-e^{-0.02836A})^{0.87915}.$$

For this function the standard error = 0.5102 feet; and the maximum error = 1.3 feet.

On a site index of 60, a 30-year-old black walnut tree would be expected to be 46.8 feet high by the first equation and 46.9 feet high by the second. Clearly, within the range of the original data, both functions give essentially the same results. For extrapolations beyond the range of the data, the exponential-monomolecular model is preferred.

Diameter

The diameter of black walnut trees on a particular site is a function of site productivity, average age of trees, and the number of trees growing on the site. A generalized function that would apply to all sites, ages, and stocking was fitted for a six-parameter function that recognized the interactions of site and age, and site and stocking. The equation for this function is:

$$D=0.50(\text{Site Index})(1.0-(0.548)e^{-0.01009(\text{Age})+0.00361(\text{SI})})e^{-0.00136(\#\text{ trees})-0.00537(\text{SI})}.$$

For this function the standard error = 0.3014 inches; and the maximum error (the maximum difference between observed and predicted values over the range of the data) = 1.060 inches.

Using this formula, the diameter of a 20-year-old tree on site 60 growing in a stand of 200 trees per acre is predicted to be:

$$D=0.510(60)(1.0-(0.548)e^{-0.01009(20)+0.00361(6}$$

$$e^{-0.00136(200)-(0.00537)(60)}$$

$$D=7.5 \text{ inches.}$$

Mortality and Residual Trees

In order to determine the total trees per acre remaining at any time, a function was fitted to describe the residual trees. This can be used to determine mortality in a plantation before thinning. The number of trees remaining will depend upon how many were planted, the site, and how long the trees have been growing.

The general equation is:

$$T=\frac{0.8757(\text{Initial Stocking})}{(1.0-e^{-0.04559(\text{Site Index})})}$$

$$e^{-0.000024(\text{Age})(\text{Initial stocking})}.$$

For this equation, the standard error = 158.9 trees; and the maximum error = 524 trees.

A plantation planted at a 10-foot square spacing (435 trees per acre) on site 60 and allowed to grow for 20 years would have:

$$T=\frac{0.8757(435)}{(1.0-e^{-0.04559(60)})}e^{-0.000024(20)(435)}$$

T=331 trees per acre.

As expected, this equation for forecasting residual trees showed the poorest fit of all the equations reported here. Nevertheless, it is fairly reliable at earlier ages on medium sites and can be used in simulating black walnut plantation growth until the first thinning.

CONCLUSIONS

The functions presented here describe the tables reported by Kellogg reasonably well. Because these functions cover a rather wide range of conditions, they should be useful for simulating growth and yield in black walnut stands until a better data base can be developed. Used with caution, these functions provide the best expression of black walnut growth and yield available at the present time.

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APPENDIX

Several extensive tables in Kellogg's 1940 report were derived from the following three equations reported by Kellogg:

1. Total basal area:

$$\log Y = 0.0930 - 0.0824 \log X_1 + 0.7082 \log X_2 + 0.4324 \log X_3$$

where:

Y=total basal area (sq. ft./acre)
X_1=original spacing in feet (square root of the area per tree)
X_2=site index (height in feet at 50 years)
X_3=stand age in years.

2. Number of trees:

$$\log Y = 5.7714 - 0.4979 \log X_1 - 0.8916 \log X_2 - 0.8609 \log X_3$$

where:

Y=number of surviving trees per acre
X_1, X_2, X_3=as above.

3. Volume in cubic feet:

$$\log Y = -0.9047 + 1.5480 \log X_2 + 0.8704 \log X_3$$

where:

Y=volume in cubic feet per acre.
X_2, X_3= as above.

U.S. Government Printing Office: 1976—669–871/185 Region No. 6

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Mathematical functions were fitted to unpublished summaries of yield data collected and reported by L. F. Kellogg in 1940 for unmanaged black walnut plantations in the Central States. They cover a wide range of conditions and provide the best data base available for simulating growth and yield in plantations.

OXFORD: 564:561:562:176.1 *Juglans nigra*. KEY WORDS: height, diameter, mortality, board-foot-volume, cubic-foot-volume.

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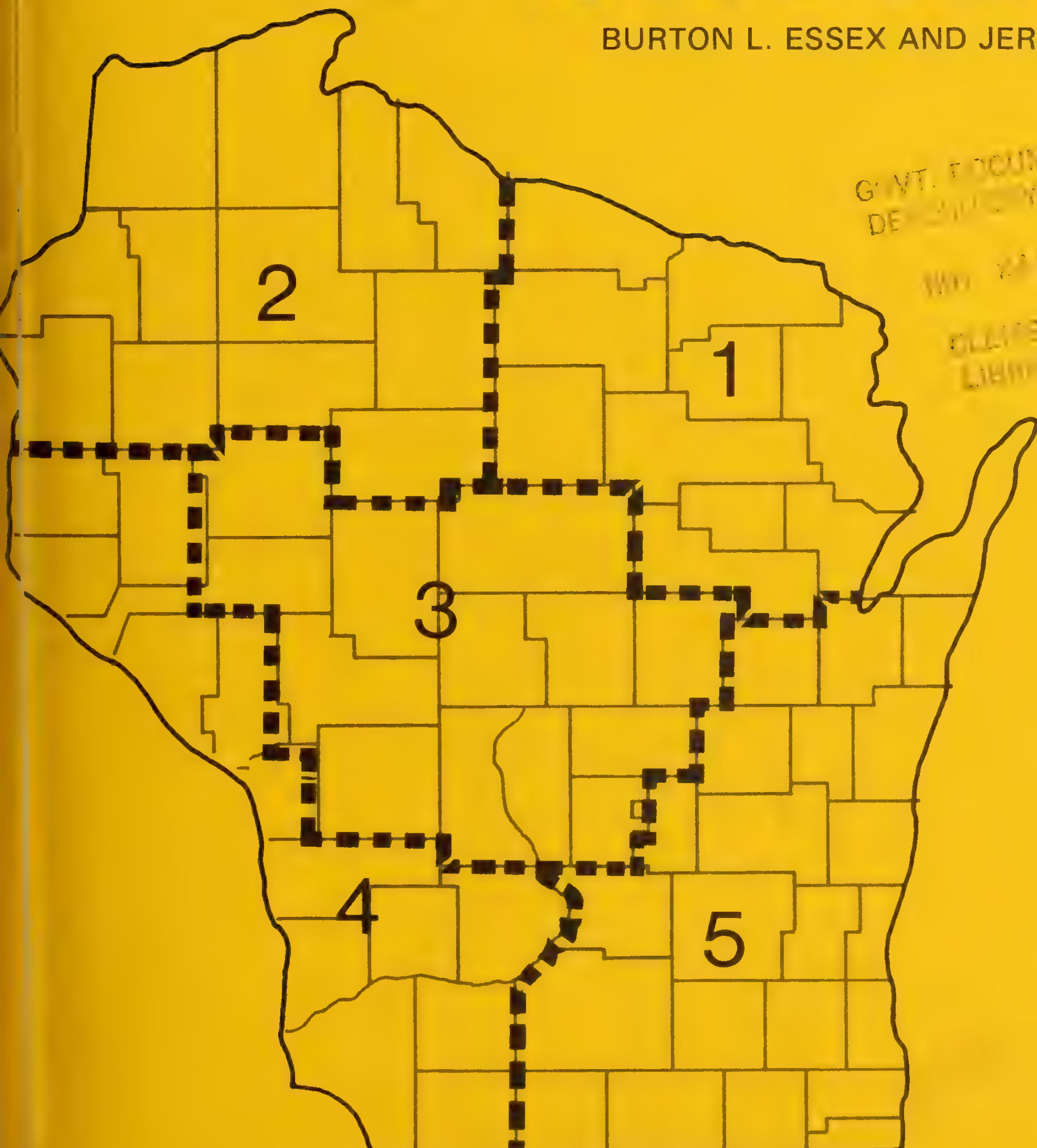
EMPIRICAL YIELD TABLES FOR WISCONSIN

BURTON L. ESSEX AND JEROLD T. HAHN



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EMPIRICAL YIELD TABLES FOR WISCONSIN

Burton L. Essex and Jerold T. Hahn

This paper presents 18 yield tables com-
iled from data gathered on 5,725 sample plots stablished during the 1968 inventory of isconsin's 5 Forest Survey Units shown in igure 1. Tables 1-12 give estimated volume er acre yield from growing-stock trees and average basal area per acre of all live trees for the 12 forest types defined on page 21. Tables 13-18 give such yields for the aspen forest type by site index classes. These tables provide a detailed picture of stand composition as measured by growing-stock volume.

Figure 1.--*Forest Survey Units in Wisconsin.*

The information presented in these tables can be used in several ways. It can be used to estimate future timber yields if one assumes that the yields shown for trees in one age class will increase in 10 years to the yields shown for the next older age class.

These tables also can be used to obtain comparative volume estimates for progressive rotation ages. For example, the aspen type occupied 3,665 M acres in Wisconsin in 1968.[1] If you harvested an equal number of acres each year, depending upon the selected rotation, the annual harvest volume estimates could be derived as follows using the yields shown in table 11:

Rotation age
35 years: 104.7 M acres X 812 ft^3=85 MM ft^3
45 years: 81.4 M acres X 1,050 ft^3=85.5 MM ft^3
55 years: 66.6 M acres X 1,104 ft^3=73.5 MM ft^3

The basal area values in these tables can be used to determine whether existing stands are stocked to their full potential because such values provide a measure of stand density when related to stand age. For example, in 1968 there were approximately 62,000 acres of aspen 50 to 60 years old in the 60 to 70 site index class in Wisconsin.[1] Yields in these stands (all species) averaged 1,254 ft^3 per acre and basal areas (growing stock and cull trees combined) averaged 97 ft^2 (table 15). Thus, the ratio of volume to basal area is 12.9 to 1. Schlaegel[2] predict that such a ratio for stands of aspen in Minnesota on similar sites and of the same age would be 25.4 to 1. If we view Schlaeg prediction as an index of stand potential, w can generalize that similar aspen sites in Wisconsin could be expected to yield roughl twice as much as these stands are producing now.

The values shown in tables 1-18 were obtained from plots established in stands that ranged from the undisturbed state to stands that had been cut repeatedly. Thus standard errors of mean volume are given in the tables to indicate this variation. Sampling errors in percents can be determin by dividing the standard error by the mean volume. For example, the sampling error fo jack pine in the 41 to 50 year age class (table 1) is ± 7.5 percent ([68.89 ft^3 ÷ 921.72 ft^3] x 100).

For each forest type, sets of seven tables (six site classes and a summary tabl that combines all site classes) are availab giving Statewide values or Forest Survey Un values (see figure 1) from the North Centra Forest Experiment Station. They may be obtained by using the Order Form in the rear of this publication, which should be addres to: PUBLICATIONS, North Central Forest Experiment Station, Folwell Avenue, St. Pau Minnesota 55108.

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[1] *Spencer, John S., Jr., and Harry W. Thorne. 1972. Wisconsin's 1968 timber resource--a perspective. USDA For. Serv. Resour. Bull. NC-15, 80 p., illus. North Cent. For. Exp. Stn., St. Paul, Minn.*

[2] *Schlaegel, Bryce E. 1971. Growth and yield of quaking aspen in north-centr Minnesota. USDA For. Serv. Res. Pap. NC- 11 p., illus. North Cent. For. Exp. Stn., St. Paul, Minn.*

Table 1.--*Estimated volume per acre yield for growing-stock trees for jack pine forest type in Wisconsin by species group and stand age*[1]

(In cubic feet)

Species group	Stand age class (years)												All
	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-120	121+	classes
SOFTWOODS													
White pine	0	2.19	6.13	0	36.91	47.27	69.00	0	0	0	0	0	10.32
Red pine	2.90	5.17	32.22	18.58	27.30	59.88	108.63	0	0	0	0	0	22.20
Jack pine	57.89	139.96	293.11	537.52	778.72	816.29	641.63	0	0	0	0	0	393.27
White spruce	0	0	0	0	0	0	0	0	0	0	0	0	0
Black spruce	0	0	1.76	0	1.76	45.51	11.98	0	0	0	0	0	3.01
Balsam fir	0	0	0	0	1.53	0	0	0	0	0	0	0	.20
Hemlock	0	0	0	0	0	0	0	0	0	0	0	0	0
Tamarack	0	0	0	0	0	0	0	0	0	0	0	0	0
Northern white-cedar	0	0	0	0	0	0	0	0	0	0	0	0	0
Other softwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	60.78	147.33	333.22	556.11	846.24	968.94	831.24	0	0	0	0	0	429.00
HARDWOODS													
White oak	0	.57	0	2.42	0	0	0	0	0	0	0	0	.72
Select red oak	0	0	7.20	9.36	3.41	0	45.43	0	0	0	0	0	5.35
Other red oak	7.22	8.81	9.79	15.85	15.02	7.50	30.72	0	0	0	0	0	11.79
Hickory	0	0	0	0	0	0	0	0	0	0	0	0	0
Yellow birch	0	0	0	0	0	0	0	0	0	0	0	0	0
Hard maple	0	0	0	0	0	0	0	0	0	0	0	0	0
Soft maple	0	0	0	0	0	0	0	0	0	0	0	0	0
Beech	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	0	0	0	0	0	0	0	0	0	0	0	0	0
Balsam poplar	0	0	0	0	0	0	0	0	0	0	0	0	0
Cottonwood	0	0	0	0	0	0	0	0	0	0	0	0	0
Paper birch	0	0	8.26	1.54	0	0	12.89	0	0	0	0	0	2.61
Bigtooth aspen	0	2.04	4.54	4.04	21.27	35.42	0	0	0	0	0	0	7.02
Quaking aspen	6.26	1.20	17.28	23.33	35.79	65.89	39.55	0	0	0	0	0	19.50
Basswood	0	0	0	0	0	0	0	0	0	0	0	0	0
Butternut	0	0	0	0	0	0	0	0	0	0	0	0	0
Black walnut	0	0	1.06	0	0	0	0	0	0	0	0	0	.26
Black cherry	0	0	0	0	0	0	0	0	0	0	0	0	0
Elm	0	0	0	0	0	0	0	0	0	0	0	0	0
Other hardwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Noncommercial spp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	13.48	12.61	48.14	56.53	75.49	108.81	128.59	0	0	0	0	0	47.25
Total all species	74.27	159.94	381.36	612.64	921.72	1,077.75	959.83	0	0	0	0	0	476.25
Number of plots	30	56	67	69	37	13	5	0	0	0	0	0	277
Standard error	16.10	19.76	34.95	40.71	68.89	121.61	89.99	0	0	0	0	0	25.30
Average basal area	19	41	63	68	77	83	84	0	0	0	0	0	58

[1]See page 21 for definition of forest types and pages 21 and 22 for species group.

Table 2.--*Estimated volume per acre yield for growing-stock trees for red pine forest type in Wisconsin by species group and stand age*[1]

(In cubic feet)

Species group	Stand age class (years): 0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-120	121+	All classes
SOFTWOODS													
White pine	12.16	5.55	51.91	46.55	410.79	148.64	431.37	460.09	400.46	1,138.04	0	0	92.18
Red pine	27.89	129.49	529.08	794.83	605.45	957.21	1,114.11	1,505.15	1,693.96	1,071.39	0	0	429.86
Jack pine	15.71	23.07	16.48	138.42	55.32	117.51	11.70	0	19.24	0	0	0	33.25
White spruce	0	0	7.28	0	16.42	17.06	0	0	17.92	0	0	0	4.33
Black spruce	0	1.71	0	0	73.77	29.55	45.74	0	0	63.08	0	0	8.01
Balsam fir	0	0	2.60	0	67.21	50.41	91.51	0	0	255.94	0	0	13.59
Hemlock	0	0	0	0	0	0	43.81	0	0	0	0	0	2.31
Tamarack	0	0	0	0	0	23.24	0	0	0	0	0	0	1.63
Northern white-cedar	0	0	0	0	0	13.59	10.90	0	0	0	0	0	1.53
Other softwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	55.76	159.82	607.33	979.80	1,228.97	1,357.22	1,749.14	1,965.25	2,131.59	2,528.46	0	0	586.39
HARDWOODS													
White oak	0	0	0	0	0	0	0	0	0	0	0	0	0
Select red oak	0	0	15.46	0	14.62	0	17.07	196.75	45.46	0	0	0	8.13
Other red oak	3.95	10.52	7.80	0	11.95	0	0	0	21.90	0	0	0	6.35
Hickory	0	0	0	0	0	0	0	0	0	0	0	0	0
Yellow birch	0	0	0	0	0	0	0	0	0	0	0	0	0
Hard maple	0	0	4.67	0	0	0	0	0	0	40.74	0	0	1.51
Soft maple	2.18	0	0	0	11.57	4.19	0	0	40.16	0	0	0	2.33
Beech	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	0	0	0	0	0	0	0	0	0	0	0	0	0
Balsam poplar	0	0	0	0	0	0	0	0	0	0	0	0	0
Cottonwood	0	0	0	0	0	0	0	0	0	0	0	0	0
Paper birch	0	5.14	7.05	0	14.45	48.22	58.91	178.74	38.08	375.38	0	0	15.76
Bigtooth aspen	0	0	0	0	0	25.81	24.57	356.58	85.61	0	0	0	8.49
Quaking aspen	16.22	0	50.75	14.35	182.92	184.21	110.75	0	75.30	226.32	0	0	46.76
Basswood	0	0	0	0	0	0	0	0	0	0	0	0	0
Butternut	0	0	0	0	0	0	0	0	0	0	0	0	0
Black walnut	0	0	4.81	0	0	0	0	0	0	0	0	0	1.18
Black cherry	0	0	0	0	0	0	0	0	0	0	0	0	0
Elm	0	0	0	0	0	0	0	0	0	0	0	0	0
Other hardwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Noncommercial spp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	22.35	15.66	90.53	14.35	235.50	262.44	211.30	732.08	306.50	642.44	0	0	90.49
Total all species	78.12	175.48	697.86	994.15	1,464.47	1,619.66	1,960.45	2,697.33	2,438.09	3,170.89	0	0	676.89
Number of plots	30	26	28	7	4	8	6	1	3	1	0	0	114
Standard error	34.90	50.36	78.41	126.10	395.08	190.04	306.17	R	492.68	R	0	0	75.42
Average basal area	12	58	78	93	104	112	118	146	120	195	0	0	65

[1] See page 21 for definition of forest types and pages 21 and 22 for species group.

Table 3.--*Estimated volume per acre yield for growing-stock trees for white pine forest type in Wisconsin by species group and stand age*[1]

(In cubic feet)

Species group	Stand age class (years) 0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-120	121+	All classes
SOFTWOODS													
White pine	0	236.32	241.45	431.78	510.33	708.51	1,060.71	786.87	875.47	1,749.25	2,058.55	2,707.69	805.98
Red pine	0	69.31	46.52	175.37	89.89	165.19	166.34	45.31	245.59	35.69	157.89	36.78	112.04
Jack pine	0	0	11.47	22.29	49.51	37.05	57.62	12.08	9.94	0	0	0	22.75
White spruce	0	0	0	0	0	33.18	65.84	0	9.73	0	31.33	0	14.30
Black spruce	0	0	0	9.96	19.24	44.57	0	18.03	0	0	0	0	10.61
Balsam fir	0	0	0	0	6.80	96.76	28.65	74.38	27.03	0	87.91	0	28.85
Hemlock	0	0	0	0	12.45	0	13.54	18.25	0	0	0	91.55	10.71
Tamarack	0	0	0	0	51.31	0	0	11.97	0	0	22.74	0	8.59
Northern white-cedar	0	0	18.37	0	0	0	0	8.48	0	0	0	199.30	15.23
Other softwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	305.63	317.80	639.41	739.53	1,085.26	1,392.69	975.38	1,167.75	1,784.94	2,358.42	3,035.32	1,029.04
HARDWOODS													
White oak	0	0	0	24.60	5.73	0	0	9.66	6.80	0	83.52	0	7.38
Select red oak	0	0	0	0	6.87	19.26	59.91	0	25.74	0	86.97	63.76	20.53
Other red oak	0	0	0	11.18	8.20	21.61	0	25.68	0	26.05	20.94	22.70	9.84
Hickory	0	0	0	0	0	0	0	0	0	0	0	0	0
Yellow birch	0	0	0	0	0	0	0	0	0	0	0	0	0
Hard maple	0	0	0	0	0	0	0	0	36.36	0	19.08	26.37	5.84
Soft maple	0	0	0	0	24.22	18.75	14.92	34.63	76.41	0	129.95	233.33	37.67
Beech	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	0	0	0	0	0	0	0	25.39	30.82	0	0	0	4.84
Balsam poplar	0	0	0	0	0	0	0	0	0	0	0	0	0
Cottonwood	0	0	0	0	0	0	9.03	0	0	0	0	0	1.07
Paper birch	0	0	10.25	32.53	88.37	32.30	29.96	12.71	13.52	0	0	67.26	29.48
Bigtooth aspen	0	0	0	12.78	0	21.13	3.11	0	62.90	0	54.89	0	12.12
Quaking aspen	0	31.76	0	144.35	84.49	156.64	94.28	106.61	8.68	0	111.15	32.46	72.53
Basswood	0	0	0	0	0	0	0	0	0	0	0	56.86	3.74
Butternut	0	0	0	0	0	0	0	0	0	0	0	0	0
Black walnut	0	9.52	0	23.63	9.26	0	0	12.76	0	0	15.66	49.52	8.72
Black cherry	0	0	0	0	0	0	0	0	0	0	0	0	0
Elm	0	0	0	0	0	0	0	0	0	0	0	0	0
Other hardwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Noncommercial spp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	41.29	10.25	249.06	227.14	269.69	211.21	227.42	261.21	26.05	522.16	552.25	213.76
Total all species	0	346.92	328.05	888.46	966.67	1,354.95	1,603.90	1,202.80	1,428.96	1,810.99	2,880.58	3,587.58	1,242.80
Number of plots	6	6	6	6	10	10	9	6	7	2	3	5	76
Standard error	0	84.89	119.47	181.96	160.79	160.34	241.93	262.75	223.02	1,739.61	1,214.77	717.88	131.27
Average basal area	6	54	47	77	88	98	100	92	91	96	150	140	84

[1] See page 21 for definition of forest types and pages 21 and 22 for species group.

Table 4.--*Estimated volume per acre yield for growing-stock trees for balsam fir-white spruce forest type in Wisconsin by species group and stand age*[1]

(In cubic feet)

Species group	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-120	121+	All classes
	Stand age class (years)												
SOFTWOODS													
White pine	22.64	12.83	9.63	3.90	24.61	34.11	5.78	8.02	444.59	0	0	21.71	20.17
Red pine	0	0	2.96	4.07	3.60	11.77	0	0	0	0	97.48	0	5.04
Jack pine	7.25	0	0	0	0	0	0	0	0	0	0	0	.52
White spruce	0	19.53	72.71	43.61	32.41	89.24	26.26	76.29	0	115.19	0	24.96	45.02
Black spruce	0	7.21	24.53	38.92	15.66	42.75	118.61	0	0	60.29	0	20.68	25.82
Balsam fir	60.01	128.97	177.53	271.83	402.21	429.45	503.89	301.30	90.88	274.78	84.13	141.64	295.29
Hemlock	2.75	1.39	20.98	10.68	15.26	9.43	80.64	0	0	52.60	34.29	53.23	15.05
Tamarack	1.95	2.36	2.59	2.80	10.27	9.07	0	13.14	0	0	0	48.32	7.13
Northern white-cedar	2.70	34.69	39.50	37.67	64.60	56.72	162.11	169.64	0	550.08	112.57	55.66	58.18
Other softwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	97.29	206.96	350.42	413.48	568.62	682.54	897.29	568.39	535.47	1,052.94	328.47	366.18	472.22
HARDWOODS													
White oak	0	0	0	2.96	0	0	0	0	0	0	0	0	.42
Select red oak	0	2.28	0	0	2.91	0	0	0	0	0	0	0	1.09
Other red oak	0	0	0	0	0	0	0	0	0	0	0	0	0
Hickory	0	0	0	0	0	0	0	0	0	0	0	0	0
Yellow birch	2.55	1.95	5.27	25.19	4.34	12.43	37.07	30.59	0	37.25	49.56	55.70	12.19
Hard maple	3.42	7.18	8.58	1.13	9.34	13.85	0	10.62	0	0	0	0	7.44
Soft maple	3.52	3.62	24.33	24.91	43.34	31.77	52.61	21.35	74.11	0	19.85	0	27.30
Beech	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	6.63	25.45	1.99	16.39	13.19	29.08	39.47	54.38	0	120.14	0	8.37	18.42
Balsam poplar	0	2.09	6.44	12.19	4.80	0	0	0	0	0	0	0	4.02
Cottonwood	0	0	0	0	0	0	0	0	0	0	0	0	0
Paper birch	13.68	35.86	23.85	46.43	46.48	66.58	56.55	101.60	0	31.64	44.91	6.09	44.02
Bigtooth aspen	0	0	0	5.51	6.29	9.45	0	0	0	0	0	0	4.16
Quaking aspen	39.36	6.53	67.93	88.64	81.52	105.52	36.21	82.34	657.32	0	130.17	22.21	72.26
Basswood	0	0	1.08	5.97	.72	7.78	0	0	0	0	0	0	2.49
Butternut	0	0	0	0	0	0	0	0	0	0	0	0	0
Black walnut	3.25	7.51	0	11.80	11.17	11.39	0	0	0	0	0	3.94	7.98
Black cherry	0	0	0	0	0	0	0	0	0	0	0	0	0
Elm	0	0	0	0	0	0	0	0	0	0	0	0	0
Other hardwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Noncommercial spp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	72.43	92.48	139.47	241.13	224.11	287.85	221.91	300.88	731.43	189.04	244.49	96.30	201.77
Total all species	169.72	299.44	489.89	654.61	792.73	970.39	1,119.20	869.27	1,266.90	1,241.98	572.96	462.48	673.99
Number of plots	19	31	29	37	74	45	9	6	1	2	3	7	263
Standard error	46.35	36.17	69.71	52.61	47.15	73.33	143.15	114.07	R	57.27	287.53	126.84	27.95
Average basal area	18	42	65	76	89	98	117	86	71	105	65	49	75

[1] See page 21 for definition of forest types and pages 21 and 22 for species group.

Table 5.--*Estimated volume per acre yield for growing-stock trees for black spruce forest type in Wisconsin by species group and stand age*[1]

(In cubic feet)

Species group	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-120	121+	All classes
	Stand age class (years)												
SOFTWOODS													
White pine	0	11.47	3.60	5.79	0	18.25	132.67	0	0	0	13.91	0	16.27
Red pine	0	0	29.00	0	12.22	32.61	110.54	0	0	0	0	0	20.19
Jack pine	0	0	0	0	0	17.17	0	23.61	0	0	0	0	3.59
White spruce	0	0	0	0	4.64	0	23.83	0	0	0	37.67	0	4.06
Black spruce	0	0	96.11	93.22	82.48	270.55	401.96	253.12	210.41	45.38	336.39	168.07	152.89
Balsam fir	0	9.95	3.87	6.23	15.11	15.72	43.42	47.09	0	0	30.92	183.98	19.64
Hemlock	0	0	0	0	0	20.55	0	0	0	0	9.74	0	3.75
Tamarack	0	77.79	32.65	23.30	39.73	31.09	29.64	0	0	0	0	37.69	30.46
Northern white-cedar	0	0	8.61	0	1.62	8.63	6.25	0	0	0	49.06	0	4.71
Other softwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	99.21	173.84	128.54	155.79	414.57	748.32	323.82	210.41	45.38	477.68	389.73	255.56
HARDWOODS													
White oak	0	0	0	0	0	0	0	0	0	0	0	0	0
Select red oak	0	0	0	0	0	10.49	0	0	0	0	0	0	1.77
Other red oak	0	0	0	0	0	0	0	0	0	0	0	0	0
Hickory	0	0	0	0	0	0	0	0	0	0	0	0	0
Yellow birch	0	0	0	0	0	0	10.64	0	0	0	26.06	0	1.62
Hard maple	0	0	0	0	0	0	12.65	0	0	0	0	0	1.00
Soft maple	0	25.62	0	0	0	3.56	16.21	0	0	0	0	0	3.15
Beech	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	0	0	0	0	0	0	0	0	0	0	0	0	0
Balsam poplar	0	0	0	0	0	0	0	0	0	0	0	0	0
Cottonwood	0	0	0	0	0	0	0	0	0	0	0	0	0
Paper birch	0	12.71	6.58	10.89	19.40	4.34	15.85	0	0	0	0	0	10.23
Bigtooth aspen	0	39.80	14.57	0	0	0	0	0	0	0	0	0	3.56
Quaking aspen	14.66	41.08	0	28.80	55.44	44.17	31.97	19.55	0	0	0	88.11	34.82
Basswood	0	0	0	0	0	0	0	0	0	0	0	0	0
Butternut	0	0	0	0	0	0	0	0	0	0	0	0	0
Black walnut	0	0	0	0	0	0	0	0	0	0	0	0	0
Black cherry	0	0	0	0	0	0	0	0	0	0	0	0	0
Elm	0	0	0	0	0	0	0	0	0	0	0	0	0
Other hardwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Noncommercial spp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	14.66	119.21	21.15	39.69	74.84	62.56	87.32	19.55	0	0	26.06	88.11	56.14
Total all species	14.66	218.43	194.99	168.23	230.63	477.13	835.63	343.37	210.41	45.38	503.74	477.85	311.70
Number of plots	3	5	11	23	23	17	8	3	1	1	3	3	101
Standard error	14.66	145.86	63.44	43.71	49.11	93.99	164.49	314.50	R	R	253.26	107.91	34.53
Average basal area	4	31	36	43	50	77	73	74	49	60	94	58	53

[1]See page 21 for definition of forest types and pages 21 and 22 for species group.

Table 6.--*Estimated volume per acre yield for growing-stock trees for northern white-cedar forest type in Wisconsin by species group and stand age*[1]

(In cubic feet)

Species group	Stand age class (years) 0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-120	121+	All classes
SOFTWOODS													
White pine	0	0	4.63	20.85	0	4.66	14.23	7.26	23.74	0	13.50	20.69	11.01
Red pine	0	0	0	8.70	0	0	0	0	0	0	0	0	.57
Jack pine	0	0	0	0	0	0	0	0	0	0	0	0	0
White spruce	0	0	5.09	19.89	18.90	19.67	6.55	9.56	7.84	0	0	0	9.69
Black spruce	0	17.16	5.91	13.10	30.35	25.57	20.73	31.76	20.43	0	66.11	160.64	33.79
Balsam fir	0	11.69	23.87	126.83	107.83	63.54	82.77	120.03	86.41	0	173.38	306.10	101.18
Hemlock	0	0	0	16.51	17.30	4.24	22.85	0	46.23	0	32.83	142.48	26.25
Tamarack	0	11.81	4.36	0	78.39	60.41	35.44	7.00	70.57	46.48	29.49	0	37.70
Northern white-cedar	313.27	224.28	99.26	433.70	391.63	502.44	479.66	518.15	789.83	892.03	978.78	995.53	558.56
Other softwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	313.27	264.94	143.11	639.58	644.40	680.53	662.23	693.76	1,045.05	938.51	1,294.09	1,625.43	778.76
HARDWOODS													
White oak	0	0	0	0	0	0	4.40	0	0	0	0	0	.65
Select red oak	0	0	0	0	0	0	0	0	0	0	0	0	0
Other red oak	0	0	0	0	0	0	0	0	0	0	0	0	0
Hickory	0	0	0	0	6.21	0	0	0	0	0	0	0	.71
Yellow birch	0	0	0	0	27.04	11.72	5.05	0	25.77	0	6.91	13.83	10.70
Hard maple	0	0	0	0	0	0	0	5.37	0	0	0	6.63	1.02
Soft maple	0	0	0	12.61	9.53	4.31	11.77	5.24	15.30	19.60	30.05	28.60	11.50
Beech	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	0	0	0	1.36	14.06	29.22	26.88	31.85	47.75	56.32	19.19	27.50	24.90
Balsam poplar	0	0	0	0	0	4.25	4.53	0	0	0	0	0	1.26
Cottonwood	0	0	0	0	0	0	0	0	0	0	0	0	0
Paper birch	63.29	95.12	11.48	23.91	9.80	50.93	36.94	73.29	29.70	0	39.65	65.01	38.48
Bigtooth aspen	0	0	0	0	0	0	0	0	0	0	0	0	0
Quaking aspen	0	29.35	0	63.96	16.53	56.66	14.78	7.89	0	17.32	19.16	0	19.57
Basswood	0	0	0	0	0	0	0	10.94	17.95	0	9.71	0	4.28
Butternut	0	0	0	0	0	0	0	0	0	0	0	0	0
Black walnut	0	37.34	0	0	15.90	23.97	25.79	27.06	30.11	49.91	86.14	0	23.88
Black cherry	0	0	0	0	0	0	0	0	0	0	0	0	0
Elm	0	0	0	0	0	0	0	0	0	0	0	0	0
Other hardwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Noncommercial spp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	63.29	161.81	11.48	101.83	99.07	181.07	130.14	161.63	166.58	143.15	210.81	141.57	136.95
Total all species	376.56	426.75	154.59	741.42	743.46	861.60	792.37	855.39	1,211.63	1,081.66	1,504.90	1,767.00	915.71
Number of plots	1	4	10	8	14	17	18	12	18	4	7	9	122
Standard error	R	110.30	53.47	195.05	103.83	145.14	126.11	141.93	145.36	314.96	323.38	344.13	62.16
Average basal area	68	76	48	98	100	112	105	100	149	135	147	125	110

[1] See page 21 for definition of forest types and pages 21 and 22 for species group.

Table 7.--*Estimated volume per acre yield for growing-stock trees for tamarack forest type in Wisconsin by species group and stand age*[1]

(In cubic feet)

Species group	Stand age class (years)												All
	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-120	121+	classes
						SOFTWOODS							
White pine	1.75	9.09	7.14	10.61	10.02	27.13	0	22.36	55.98	137.33	0	0	12.75
Red pine	0	0	0	0	0	4.64	8.82	0	0	0	0	0	1.38
Jack pine	0	2.52	0	6.73	0	0	0	0	0	0	0	0	.94
White spruce	0	0	0	0	0	3.97	22.79	8.82	0	0	0	0	2.84
Black spruce	1.71	26.91	0	28.63	43.31	65.41	52.58	0	37.76	119.76	0	0	30.38
Balsam fir	0	9.28	0	11.85	12.78	47.29	24.56	64.87	0	0	0	0	17.47
Hemlock	0	3.09	0	0	0	0	0	9.85	0	0	0	0	1.09
Tamarack	30.49	73.52	71.41	225.82	291.74	371.94	395.75	590.14	473.09	204.97	0	0	222.58
Northern white-cedar	0	0	0	22.85	8.72	45.79	5.83	7.53	0	0	0	0	11.09
Other softwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	33.95	124.41	78.55	306.49	366.57	566.17	510.33	703.56	566.83	462.07	0	0	300.53
						HARDWOODS							
White oak	0	0	0	0	0	0	0	0	0	0	0	0	0
Select red oak	0	0	0	0	3.75	0	0	0	0	0	0	0	.64
Other red oak	0	0	0	0	0	0	0	0	0	0	0	0	0
Hickory	0	0	0	0	0	0	0	0	0	0	0	0	0
Yellow birch	0	0	0	0	4.16	0	0	6.19	0	0	0	0	1.07
Hard maple	0	0	0	0	0	0	0	0	0	0	0	0	0
Soft maple	0	0	7.91	0	7.37	0	7.96	0	0	0	0	0	2.47
Beech	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	0	0	0	0	0	0	0	0	0	0	0	0	0
Balsam poplar	0	0	0	0	0	4.18	0	0	0	0	0	0	.64
Cottonwood	0	0	0	0	0	0	0	0	0	0	0	0	0
Paper birch	2.95	0	25.67	6.89	30.47	17.42	14.53	10.32	0	63.26	0	0	13.22
Bigtooth aspen	0	0	0	0	0	0	0	0	0	0	0	0	0
Quaking aspen	2.98	0	36.98	0	0	16.44	0	7.76	0	0	0	0	6.33
Basswood	0	0	0	0	0	0	0	0	0	0	0	0	0
Butternut	0	0	0	0	0	0	0	0	0	0	0	0	0
Black walnut	0	0	0	0	0	11.45	0	13.11	27.74	0	0	0	3.02
Black cherry	0	0	0	0	0	0	0	0	0	0	0	0	0
Elm	0	0	0	0	0	0	0	0	0	0	0	0	0
Other hardwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Noncommercial spp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	5.93	0	70.56	6.89	45.76	49.48	22.48	37.38	27.74	63.26	0	0	27.39
Total all species	39.88	124.41	149.12	313.38	412.33	615.64	532.82	740.93	594.57	525.33	0	0	327.92
Number of plots	20	18	8	8	18	16	8	6	2	1	0	0	105
Standard error	12.77	32.01	62.10	100.29	87.25	128.50	128.99	186.87	108.53	R	0	0	37.19
Average basal area	7	25	37	43	50	64	50	62	59	90	0	0	39

[1]See page 21 for definition of forest types and pages 21 and 22 for species group.

Table 8.--*Estimated volume per acre yield for growing-stock trees for oak-hickory forest type in Wisconsin by species group and stand age*[1]

(In cubic feet)

Species group	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-120	121+	All classes
	Stand age class (years)												
SOFTWOODS													
White pine	.85	2.81	4.99	9.85	16.09	9.61	27.47	21.67	9.11	4.50	11.76	31.07	12.02
Red pine	.92	4.56	0	5.69	8.43	5.72	13.74	8.96	3.18	.92	0	0	5.26
Jack pine	9.68	18.89	8.52	25.88	22.40	25.56	19.53	7.44	7.75	3.05	.70	0	15.48
White spruce	0	0	0	0	0	0	0	0	0	0	0	0	0
Black spruce	0	0	0	0	0	0	0	0	0	0	0	0	0
Balsam fir	0	0	0	0	0	0	0	0	0	0	0	0	0
Hemlock	0	0	0	0	0	.73	0	0	0	0	0	0	.09
Tamarack	0	.90	0	0	1.00	1.20	0	0	0	0	0	0	.34
Northern white-cedar	0	0	0	0	0	0	0	0	0	0	0	0	0
Other softwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	11.46	27.17	13.51	41.42	47.93	42.82	60.75	38.07	20.04	8.47	12.46	31.07	33.18
HARDWOODS													
White oak	14.66	27.84	72.02	45.69	75.84	103.65	145.56	183.71	189.21	241.24	297.83	258.88	116.43
Select red oak	21.33	38.85	96.92	190.41	260.00	269.91	325.71	357.14	399.43	453.77	343.91	519.61	251.62
Other red oak	33.11	26.00	50.61	126.43	135.41	166.05	172.56	135.33	185.22	85.92	130.99	113.19	119.36
Hickory	6.44	7.30	39.94	28.67	30.50	31.30	33.99	40.87	52.06	56.96	42.81	35.18	31.86
Yellow birch	0	0	0	0	0	.94	0	.51	0	0	0	1.78	.20
Hard maple	0	0	0	3.41	10.86	12.23	19.20	14.00	15.30	20.41	7.89	16.79	9.47
Soft maple	4.30	1.68	21.20	15.45	29.42	21.06	57.24	20.59	11.16	30.29	15.37	47.45	22.01
Beech	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	.53	.77	2.80	6.53	10.42	5.18	13.50	10.24	9.11	13.00	3.95	12.91	7.24
Balsam poplar	0	0	0	.39	0	.50	0	.66	0	0	0	0	.17
Cottonwood	0	1.79	0	.43	1.53	2.51	0	3.36	2.77	0	0	0	1.14
Paper birch	6.00	6.79	34.98	35.22	54.40	39.67	29.91	13.94	17.14	24.74	9.24	4.90	27.22
Bigtooth aspen	5.52	13.91	34.84	59.81	64.06	47.20	63.29	51.13	29.64	42.29	36.33	31.11	43.48
Quaking aspen	3.04	10.91	20.45	72.34	60.77	26.58	26.74	19.34	19.34	20.72	10.01	11.63	31.21
Basswood	1.30	2.33	11.90	12.99	16.65	10.86	6.40	20.50	14.74	22.41	18.63	40.34	13.13
Butternut	1.37	0	5.29	2.08	2.61	2.88	.49	3.54	2.98	7.03	.75	4.01	2.49
Black walnut	2.90	5.98	14.71	16.70	16.19	14.06	31.01	27.96	30.19	34.29	39.24	62.15	20.92
Black cherry	0	0	0	0	0	0	0	0	0	0	0	0	0
Elm	0	0	0	0	0	0	0	0	0	0	0	0	0
Other hardwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Noncommercial spp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	100.49	144.15	405.66	616.55	768.67	754.63	925.60	902.81	978.28	1,053.07	956.95	1,159.90	697.95
Total all species	111.95	171.32	419.17	657.97	816.60	797.45	986.35	940.87	998.33	1,061.54	969.41	1,190.97	731.13
Number of plots	136	76	64	176	185	152	115	102	88	70	81	37	1,282
Standard error	13.38	17.16	50.15	33.15	35.29	37.75	50.35	57.05	63.19	75.95	70.69	130.30	16.14
Average basal area	28	50	68	79	85	82	88	85	84	90	83	97	76

[1] See page 21 for definition of forest types and pages 21 and 22 for species group.

Table 9.--*Estimated volume per acre yield for growing-stock trees for elm-ash-cottonwood forest type in Wisconsin by species group and stand age*[1]

(In cubic feet)

Species group	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-120	121+	All classes
	Stand age class (years)												
SOFTWOODS													
White pine	0	4.31	14.89	21.94	3.44	17.18	12.88	36.82	24.64	4.03	25.79	0	13.58
Red pine	.78	1.72	3.42	1.33	0	0	0	0	0	0	0	0	.69
Jack pine	0	0	4.76	.84	1.63	2.33	0	0	0	0	0	0	1.02
White spruce	.86	3.98	2.32	4.93	6.78	3.73	6.47	7.85	19.84	4.82	0	34.91	5.82
Black spruce	0	1.32	0	1.36	2.00	2.37	0	5.42	0	0	13.73	0	1.83
Balsam fir	4.16	9.93	15.62	23.55	22.95	38.08	36.69	28.90	38.10	33.79	24.49	68.21	25.51
Hemlock	.72	2.94	0	1.94	9.63	16.63	27.71	31.57	11.75	5.90	33.75	20.06	12.15
Tamarack	7.01	5.69	2.56	4.08	6.09	10.28	11.15	13.91	7.89	2.07	0	0	6.79
Northern white-cedar	2.06	8.00	3.27	22.62	31.63	75.66	51.21	84.14	20.95	71.25	51.25	180.70	39.64
Other softwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	15.60	37.89	46.83	82.59	84.16	166.27	146.11	208.61	123.17	121.86	149.01	303.88	107.04
HARDWOODS													
White oak	2.18	0	3.32	5.41	2.60	18.49	16.07	26.18	41.73	30.51	14.41	4.60	11.61
Select red oak	1.04	0	2.23	6.81	15.95	10.83	16.16	7.95	12.56	15.82	2.23	0	8.21
Other red oak	0	0	1.62	0	4.23	1.53	0	4.11	2.11	0	0	0	1.22
Hickory	.98	0	0	0	1.48	0	2.38	0	0	0	0	0	.57
Yellow birch	1.17	0	6.39	7.18	20.24	19.22	17.19	14.19	25.84	15.83	26.18	76.93	14.49
Hard maple	1.17	1.52	7.71	.87	17.06	10.56	4.91	30.64	27.76	20.82	6.04	0	9.45
Soft maple	11.49	23.30	51.20	97.21	162.02	170.21	199.31	151.87	226.52	150.13	393.16	74.69	132.54
Beech	0	0	0	3.71	0	.96	0	2.38	0	0	0	0	.74
Ash	31.93	43.34	91.98	124.32	170.60	242.40	263.09	231.31	404.04	501.40	255.65	434.18	190.13
Balsam poplar	0	1.49	2.20	0	6.31	16.47	4.09	4.44	0	3.96	0	0	4.17
Cottonwood	1.16	4.52	0	23.47	8.53	13.31	3.46	15.33	0	45.85	38.16	0	10.97
Paper birch	2.68	8.09	27.73	47.50	43.48	33.14	23.03	32.83	41.75	8.09	15.91	2.55	26.86
Bigtooth aspen	0	5.60	5.97	14.20	5.32	9.05	11.09	0	6.82	4.22	0	0	6.36
Quaking aspen	7.91	19.37	32.95	69.95	75.38	36.79	38.38	26.34	47.25	5.25	2.10	12.13	36.95
Basswood	2.39	0	1.54	17.44	24.33	14.98	35.25	21.67	29.52	69.70	15.54	73.13	19.44
Butternut	0	0	0	0	0	0	1.10	0	0	0	0	0	.13
Black walnut	28.77	27.47	100.39	95.02	152.99	246.73	213.41	273.11	348.45	422.52	312.12	120.82	170.52
Black cherry	0	0	0	0	0	0	0	0	0	0	0	0	0
Elm	0	0	0	0	0	0	0	0	0	0	0	0	0
Other hardwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Noncommercial spp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	92.88	134.69	335.21	513.10	710.51	844.66	848.94	842.34	1,214.36	1,294.11	1,081.49	799.03	644.34
Total all species	108.48	172.58	382.05	595.69	794.67	1,010.92	995.05	1,050.95	1,337.53	1,415.96	1,230.51	1,102.91	751.38
Number of plots	69	45	51	71	68	78	69	37	30	20	28	14	580
Standard error	16.04	27.06	42.59	46.77	73.56	68.90	70.49	106.98	101.65	166.97	128.68	122.14	26.57
Average basal area	18	36	55	67	76	87	87	88	106	109	92	106	71

[1]See page 21 for definition of forest types and pages 21 and 22 for species group.

Table 10.--*Estimated volume per acre yield for growing-stock trees for maple-beech-birch forest type in Wisconsin by species group and stand age*[1]

(In cubic feet)

Species group	Stand age class (years) 0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-120	121+	All classes
SOFTWOODS													
White pine	16.27	9.85	28.35	13.97	20.71	19.72	42.11	39.94	19.36	29.22	75.90	82.22	30.26
Red pine	1.25	.99	1.23	2.06	2.13	2.63	13.74	0	2.85	3.26	12.39	4.43	3.73
Jack pine	.45	0	.57	.27	0	.91	.87	0	0	0	.63	0	.34
White spruce	0	.85	.84	2.25	4.31	4.06	.75	2.03	3.48	1.04	2.02	5.56	2.67
Black spruce	0	0	0	.69	.42	1.27	.46	0	0	1.81	1.24	0	.55
Balsam fir	4.11	12.59	14.24	17.38	25.40	21.48	18.10	20.75	22.63	14.87	34.68	21.56	19.94
Hemlock	9.43	9.69	8.10	8.37	29.17	29.77	29.61	64.29	62.62	160.78	246.76	582.55	84.30
Tamarack	0	0	0	.25	0	1.95	1.91	0	0	0	0	1.50	.59
Northern white-cedar	7.60	2.01	1.06	2.13	8.30	10.56	3.65	8.82	30.61	27.55	44.03	59.89	14.42
Other softwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	39.12	35.97	54.40	47.37	90.44	92.35	111.20	135.84	141.56	238.53	417.64	757.71	156.80
HARDWOODS													
White oak	1.59	1.20	4.61	11.41	15.17	9.20	22.32	32.26	21.81	37.10	8.60	22.09	15.10
Select red oak	11.28	18.76	30.17	41.95	46.89	60.52	69.10	74.14	69.64	104.19	50.80	57.70	52.84
Other red oak	4.72	1.34	3.91	4.33	3.51	.91	10.59	3.18	7.38	2.97	5.83	0	3.88
Hickory	5.75	1.02	3.01	14.61	6.18	6.27	8.68	13.88	12.51	9.40	21.65	6.76	8.93
Yellow birch	1.77	2.01	10.96	15.99	31.76	46.09	32.61	43.96	80.51	89.39	85.71	183.42	47.42
Hard maple	9.94	31.75	44.62	114.30	199.69	237.72	299.61	262.98	335.07	372.34	459.40	505.63	231.16
Soft maple	25.35	31.44	62.84	68.16	89.85	117.28	124.84	109.63	54.18	89.30	53.34	67.28	81.95
Beech	1.67	0	0	1.06	2.17	5.89	14.48	0	7.19	13.65	41.30	26.75	7.96
Ash	3.64	16.29	24.50	41.90	59.89	81.94	49.85	70.04	37.14	81.89	30.41	49.40	50.77
Balsam poplar	0	0	4.21	0	.49	4.57	.51	0	1.03	0	0	0	1.12
Cottonwood	0	0	0	0	0	1.90	1.83	1.17	3.75	.93	0	0	.78
Paper birch	11.54	30.85	49.63	46.25	68.28	70.93	50.22	28.45	41.58	24.37	18.08	29.07	46.25
Bigtooth aspen	2.63	10.96	13.21	19.26	17.78	15.66	31.42	7.63	6.45	18.18	5.78	3.80	14.44
Quaking aspen	29.54	60.86	64.47	98.03	81.30	67.15	41.02	24.24	25.16	.82	37.79	9.82	54.40
Basswood	14.76	37.30	58.92	158.72	155.63	183.92	106.63	138.70	127.89	139.46	84.55	132.23	127.17
Butternut	1.77	.71	0	2.66	3.07	1.79	4.34	5.27	5.90	3.80	6.91	2.08	3.05
Black walnut	36.33	26.17	66.30	94.43	92.55	141.44	141.56	187.37	155.62	150.58	176.14	164.35	118.97
Black cherry	0	0	0	0	0	0	0	0	0	0	0	0	0
Elm	0	0	0	0	0	0	0	0	0	0	0	0	0
Other hardwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Noncommercial spp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	162.27	270.65	441.36	733.04	874.21	1,053.20	1,009.59	1,002.88	992.82	1,138.37	1,086.30	1,260.38	866.20
Total all species	201.39	306.62	495.75	780.40	964.65	1,145.55	1,120.79	1,138.72	1,134.37	1,376.90	1,503.94	2,018.09	1,023.01
Number of plots	79	79	90	185	254	222	131	105	83	73	83	102	1,486
Standard error	24.87	24.25	33.91	31.40	28.24	34.21	46.36	54.55	69.91	90.40	78.65	90.33	17.78
Average basal area	31	58	72	88	97	99	94	95	92	99	104	118	90

[1]See page 21 for definition of forest types and pages 21 and 22 for species group.

Table 11.--*Estimated volume per acre yield for growing-stock trees for aspen forest type in Wisconsin by species group and stand age*[1]

(In cubic feet)

Species group	Stand age class (years) 0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-120	121+	All classes
SOFTWOODS													
White pine	4.19	5.45	7.83	7.38	22.50	42.24	100.61	145.61	52.36	155.30	0	50.33	12.11
Red pine	5.65	6.00	6.17	9.45	21.50	21.20	60.19	0	0	42.90	0	0	10.62
Jack pine	5.35	7.09	14.55	13.41	14.04	0	0	0	0	0	0	0	10.30
White spruce	3.20	2.23	3.15	3.65	6.41	4.78	15.46	24.29	0	0	0	0	3.94
Black spruce	.62	1.54	.42	1.85	4.79	1.99	5.67	25.57	0	0	0	16.78	1.98
Balsam fir	8.40	6.62	8.84	20.77	22.80	59.29	54.37	0	0	73.36	0	161.78	16.92
Hemlock	.65	.81	.69	.19	.77	0	6.40	0	0	0	0	0	.60
Tamarack	3.59	3.02	1.19	3.33	5.64	.99	0	26.14	12.90	0	0	0	3.36
Northern white-cedar	1.67	2.02	.92	3.23	3.80	6.64	25.57	0	0	0	0	0	2.84
Other softwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	33.32	34.79	43.75	63.26	102.24	137.12	268.28	221.60	65.26	271.56	0	228.89	62.67
HARDWOODS													
White oak	1.15	4.09	3.90	8.93	11.07	5.26	18.91	0	19.87	0	0	0	6.18
Select red oak	3.25	6.20	7.23	30.12	35.61	48.75	14.11	14.48	499.38	0	0	0	19.97
Other red oak	2.06	.71	5.42	7.22	9.25	2.92	14.28	0	0	0	0	0	5.11
Hickory	1.11	.19	0	1.00	.21	0	0	32.95	0	0	0	0	.67
Yellow birch	.42	.57	.87	.64	2.21	2.11	0	0	0	0	0	0	.92
Hard maple	2.61	2.10	2.92	5.14	7.52	7.88	5.53	37.46	0	0	0	0	4.42
Soft maple	5.13	8.21	9.00	22.37	32.63	43.86	32.47	50.73	162.62	0	0	56.24	17.85
Beech	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	4.14	5.04	3.17	6.76	13.88	8.02	28.27	51.93	26.18	0	0	0	7.05
Balsam poplar	1.57	2.41	3.26	4.62	10.53	20.30	8.42	77.32	0	0	0	0	5.28
Cottonwood	0	0	0	.99	3.13	0	0	0	0	0	0	0	.79
Paper birch	13.47	23.38	29.08	59.96	78.66	104.05	120.68	29.29	0	31.16	0	84.09	45.81
Bigtooth aspen	6.08	15.31	42.69	124.81	208.55	178.08	143.22	258.01	355.93	93.31	0	0	88.92
Quaking aspen	76.26	143.50	259.55	461.67	510.30	505.72	475.34	369.93	235.01	70.94	0	202.21	314.46
Basswood	2.03	2.04	2.17	4.95	8.47	10.72	4.02	0	0	0	0	18.23	4.31
Butternut	0	0	.18	.53	.55	2.37	0	0	0	0	0	0	.36
Black walnut	5.46	5.81	6.03	9.60	15.42	27.07	22.43	48.61	21.59	0	0	0	9.55
Black cherry	0	0	0	0	0	0	0	0	0	0	0	0	0
Elm	0	0	0	0	0	0	0	0	0	0	0	0	0
Other hardwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Noncommercial spp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	124.73	219.55	375.46	749.30	947.98	967.12	887.67	970.72	1,320.58	195.41	0	360.78	531.65
Total all species	158.04	254.34	419.21	812.56	1,050.23	1,104.24	1,155.95	1,192.32	1,385.83	466.98	0	589.67	594.32
Number of plots	326	239	224	451	260	61	17	5	3	2	0	4	1,592
Standard error	9.35	13.60	21.47	21.53	33.48	77.10	161.86	230.41	653.93	466.98	0	352.77	13.24
Average basal area	25	45	55	74	88	85	88	92	90	40	0	53	60

[1]See page 21 for forest types and pages 21 and 22 for species group.

Table 12.--*Estimated volume per acre yield for growing-stock trees for paper birch forest type in Wisconsin by species group and stand age*[1]

(In cubic feet)

Species group	Stand age class (years) 0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-120	121+	All classes
SOFTWOODS													
White pine	2.21	1.91	2.92	1.93	25.58	31.57	74.02	83.30	101.00	0	0	0	16.02
Red pine	0	0	0	0	15.58	60.17	36.35	0	60.25	0	0	0	14.14
Jack pine	0	0	2.26	14.02	6.07	9.10	0	0	0	0	0	0	6.17
White spruce	0	0	0	2.18	8.01	2.09	20.55	295.11	0	0	0	0	4.67
Black spruce	0	0	4.04	0	2.19	3.64	0	0	0	0	0	0	1.56
Balsam fir	0	4.21	19.79	24.78	37.98	78.84	124.63	0	0	0	77.02	0	33.59
Hemlock	0	0	10.47	1.27	2.86	10.31	17.19	0	0	0	0	0	4.46
Tamarack	0	3.91	5.22	0	4.31	6.97	7.37	0	0	0	0	0	3.35
Northern white-cedar	0	0	21.63	3.94	0	2.05	154.88	0	0	0	64.64	0	10.26
Other softwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	2.21	10.03	66.33	48.12	102.60	204.74	435.00	378.41	161.25	0	141.66	0	94.23
HARDWOODS													
White oak	0	12.41	10.57	6.20	3.17	1.99	18.33	0	67.29	0	70.51	0	6.95
Select red oak	3.60	0	33.59	62.23	29.86	98.94	56.09	0	262.09	0	0	303.60	46.51
Other red oak	0	0	3.67	6.11	2.00	7.38	0	0	0	0	0	0	3.38
Hickory	0	4.36	1.56	3.68	0	0	0	0	0	0	0	0	1.49
Yellow birch	0	1.13	5.89	0	4.49	4.09	4.42	0	0	0	0	0	2.69
Hard maple	0	0	1.99	8.96	32.11	22.96	13.27	0	119.25	0	0	0	14.97
Soft maple	5.93	7.53	11.02	35.92	49.48	59.03	35.83	0	69.41	0	0	0	32.98
Beech	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	0	2.80	5.92	7.26	11.63	11.51	28.38	0	0	0	115.79	0	8.61
Balsam poplar	0	0	6.22	0	0	3.61	81.77	0	0	0	271.57	0	5.59
Cottonwood	0	0	0	1.67	0	0	24.32	0	0	0	0	0	1.30
Paper birch	47.81	87.18	225.67	413.79	485.79	617.83	661.20	126.52	564.07	0	144.32	120.95	371.08
Bigtooth aspen	0	4.10	14.32	18.10	49.70	62.05	48.84	0	0	0	0	0	28.50
Quaking aspen	7.53	23.46	21.24	96.92	129.36	144.97	124.23	216.70	105.60	0	0	100.15	85.69
Basswood	0	0	4.87	6.75	10.71	1.64	15.86	0	0	0	152.74	0	6.16
Butternut	0	0	1.85	0	0	0	0	0	0	0	0	0	.25
Black walnut	0	0	13.53	17.15	4.07	1.82	70.17	0	0	0	0	0	9.60
Black cherry	0	0	0	0	0	0	0	0	0	0	0	0	0
Elm	0	0	0	0	0	0	0	0	0	0	0	0	0
Other hardwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Noncommercial spp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	64.88	142.96	361.92	684.73	812.38	1,037.83	1,182.70	343.21	1,187.71	0	754.92	524.70	625.76
Total all species	67.09	152.98	428.25	732.86	914.98	1,242.57	1,617.69	721.62	1,348.96	0	896.58	524.70	719.99
Number of plots	24	24	32	54	55	33	9	1	3	0	1	1	237
Standard error	21.72	38.80	69.44	51.89	49.66	102.91	212.58	R	767.63	0	R	R	37.62
Average basal area	19	33	60	76	83	96	114	52	94	0	64	49	70

[1]See page 21 for forest types and pages 21 and 22 for species group.

Table 13.--*Estimated volume per acre yield from growing-stock trees for the aspen type on sites having site indexes 0 to 50 in Wisconsin by species group and stand age*[1]

(In cubic feet)

Species group	Stand age class (years) 0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-120	121+	All classes
SOFTWOODS													
White pine	13.70	0	8.99	5.90	35.75	145.98	0	0	0	0	0	0	14.44
Red pine	1.83	1.77	0	7.70	0	10.95	0	0	0	0	0	0	3.13
Jack pine	4.73	1.67	14.47	17.19	0	0	0	0	0	0	0	0	7.94
White spruce	11.52	0	12.29	14.22	24.56	0	28.80	0	0	0	0	0	11.07
Black spruce	0	4.22	2.36	3.18	64.28	0	0	127.87	0	0	0	0	8.52
Balsam fir	2.39	5.85	10.05	8.20	53.37	60.12	122.06	0	0	0	0	0	14.53
Hemlock	.68	0	4.74	0	3.25	0	36.28	0	0	0	0	0	1.88
Tamarack	0	4.24	0	2.53	4.27	0	0	130.69	0	0	0	0	2.74
Northern white-cedar	0	2.45	2.53	1.47	11.01	0	106.53	0	0	0	0	0	4.36
Other softwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	34.84	20.21	55.42	60.39	196.48	217.05	293.66	258.56	0	0	0	0	68.62
HARDWOODS													
White oak	0	6.65	0	3.31	0	0	20.63	0	0	0	0	0	2.57
Select red oak	0	4.56	0	0	0	0	0	0	0	0	0	0	.90
Other red oak	0	0	0	0	14.68	0	80.90	0	0	0	0	0	2.95
Hickory	0	0	0	2.96	0	0	0	0	0	0	0	0	.75
Yellow birch	1.04	0	0	0	0	8.48	0	0	0	0	0	0	.56
Hard maple	5.15	0	9.56	4.36	6.88	0	0	0	0	0	0	0	4.40
Soft maple	1.51	1.97	2.78	.48	12.72	61.37	53.19	0	0	0	0	0	5.59
Beech	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	4.26	5.43	0	4.37	22.88	20.51	64.09	0	0	0	0	0	7.30
Balsam poplar	0	11.87	7.86	3.44	5.15	0	0	0	0	0	0	0	4.79
Cottonwood	0	0	0	0	0	0	0	0	0	0	0	0	0
Paper birch	1.99	8.29	13.56	42.56	108.30	264.65	50.09	0	0	0	0	0	34.40
Bigtooth aspen	0	16.78	0	28.78	57.85	0	71.39	0	0	0	0	0	17.13
Quaking aspen	51.03	85.17	133.16	328.69	346.45	218.86	153.04	131.59	0	0	0	0	173.85
Basswood	4.72	0	4.76	4.73	0	0	0	0	0	0	0	0	3.09
Butternut	0	0	0	0	0	0	0	0	0	0	0	0	0
Black walnut	3.24	10.66	3.22	10.46	20.01	0	0	0	0	0	0	0	7.80
Black cherry	0	0	0	0	0	0	0	0	0	0	0	0	0
Elm	0	0	0	0	0	0	0	0	0	0	0	0	0
Other hardwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Noncommercial spp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	72.94	151.40	174.90	434.14	594.91	573.88	493.32	131.59	0	0	0	0	266.08
Total all species	107.79	171.60	230.32	494.54	791.39	790.93	786.98	390.15	0	0	0	0	334.70
Number of plots	38	29	21	37	13	5	3	1	0	0	0	0	147
Standard error	25.85	37.89	57.29	62.43	145.97	300.34	168.71	R	0	0	0	0	32.19
Average basal area	18	30	35	50	71	65	84	41	0	0	0	0	39

[1] See page 21 for definition of forest types and pages 21 and 22 for species group.

Table 14.--*Estimated volume per acre yield from growing-stock trees for the aspen type on sites having site indexes 51 to 60 in Wisconsin by species group and stand age*[1]

(In cubic feet)

Species group	Stand age class (years)												All
	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-120	121+	classes
SOFTWOODS													
White pine	4.04	3.45	5.26	6.35	17.49	15.66	0	0	52.98	0	0	0	7.06
Red pine	4.18	8.04	3.09	10.27	37.50	0	0	0	0	0	0	0	10.26
Jack pine	3.71	15.94	14.06	20.12	22.56	0	0	0	0	0	0	0	12.88
White spruce	.51	4.58	5.01	2.09	3.93	0	13.97	121.44	0	0	0	0	3.17
Black spruce	.64	0	0	4.51	1.30	0	11.95	0	0	0	0	0	1.43
Balsam fir	8.46	6.49	4.15	19.88	31.78	23.97	46.19	0	0	0	0	237.17	14.94
Hemlock	0	0	1.10	0	0	0	0	0	0	0	0	0	.16
Tamarack	6.90	5.24	3.29	17.37	5.71	0	0	0	0	0	0	0	7.52
Northern white-cedar	0	.68	3.12	9.08	2.19	0	0	0	0	0	0	0	2.67
Other softwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	28.45	44.41	39.09	89.67	122.46	39.63	72.11	121.44	52.98	0	0	237.17	60.10
HARDWOODS													
White oak	1.54	2.91	.90	2.69	8.16	4.66	0	0	0	0	0	0	2.93
Select red oak	5.24	6.47	1.30	16.64	10.41	23.78	36.60	0	341.03	0	0	0	10.12
Other red oak	1.10	.99	6.37	7.75	2.98	0	0	0	0	0	0	0	3.36
Hickory	0	0	0	0	0	0	0	0	0	0	0	0	0
Yellow birch	0	0	1.23	0	0	0	0	0	0	0	0	0	.18
Hard maple	2.20	4.50	0	.63	4.55	0	0	187.28	0	0	0	0	2.69
Soft maple	5.40	7.95	2.28	18.66	19.37	54.31	11.65	253.64	487.86	0	0	0	14.41
Beech	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	7.02	8.24	2.41	.62	7.28	7.96	0	259.67	78.55	0	0	0	6.20
Balsam poplar	.77	0	2.91	10.61	14.26	18.56	0	0	0	0	0	0	5.58
Cottonwood	0	0	0	1.82	8.99	0	0	0	0	0	0	0	1.63
Paper birch	10.46	24.52	9.97	38.14	36.22	41.34	0	0	0	0	0	272.40	23.75
Bigtooth aspen	2.62	10.28	11.27	68.22	70.24	24.96	346.07	0	0	0	0	0	33.75
Quaking aspen	57.10	104.08	118.36	317.30	378.08	377.72	514.32	769.68	630.06	0	0	0	195.33
Basswood	3.36	.90	2.04	.98	9.61	12.77	0	0	0	0	0	0	3.51
Butternut	0	0	0	0	0	0	0	0	0	0	0	0	0
Black walnut	3.42	3.73	2.81	9.85	3.88	45.64	38.91	121.75	64.77	0	0	0	7.67
Black cherry	0	0	0	0	0	0	0	0	0	0	0	0	0
Elm	0	0	0	0	0	0	0	0	0	0	0	0	0
Other hardwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Noncommercial spp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	100.25	174.57	161.86	493.90	574.02	611.71	947.55	1,592.02	1,602.26	0	0	272.40	311.11
Total all species	128.70	218.99	200.95	583.57	696.48	651.34	1,019.66	1,713.46	1,655.24	0	0	509.57	371.21
Number of plots	94	55	49	66	47	15	5	1	1	0	0	1	334
Standard error	15.87	22.94	18.69	38.54	46.08	67.80	284.83	R	R	0	0	R	19.21
Average basal area	20	39	41	62	71	61	70	124	128	0	0	67	45

[1] See page 21 for definition of forest types and pages 21 and 22 for species group.

Table 15.--*Estimated volume per acre yield from growing-stock trees for the aspen type on sites having site indexes 61 to 70 in Wisconsin by species group and stand age*[1]

(In cubic feet)

Species group	Stand age class (years) 0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-120	121+	All classes
SOFTWOODS													
White pine	1.99	11.95	8.54	13.87	16.91	44.38	267.91	728.03	104.09	0	0	0	16.19
Red pine	7.31	1.99	7.79	10.17	21.05	25.33	42.57	0	0	0	0	0	11.41
Jack pine	5.13	5.22	28.54	19.48	16.04	0	0	0	0	0	0	0	13.22
White spruce	3.22	1.50	2.74	1.73	7.06	10.80	0	0	0	0	0	0	3.68
Black spruce	1.22	0	.90	2.69	3.13	4.49	9.17	0	0	0	0	0	2.05
Balsam fir	8.16	6.39	9.79	21.46	22.34	107.37	12.06	0	0	0	0	0	19.87
Hemlock	.95	.81	0	0	1.56	0	0	0	0	0	0	0	.64
Tamarack	4.50	2.87	0	1.34	6.66	2.25	0	0	38.70	0	0	0	3.31
Northern white-cedar	1.04	.83	0	1.67	1.22	14.99	0	0	0	0	0	0	1.85
Other softwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	33.53	31.55	58.31	72.42	95.97	209.61	331.71	728.03	142.79	0	0	0	72.22
HARDWOODS													
White oak	.96	1.70	3.71	7.76	5.24	4.88	64.91	0	0	0	0	0	4.75
Select red oak	2.05	7.26	7.48	21.65	29.38	36.10	14.22	72.41	0	0	0	0	16.14
Other red oak	3.00	.94	5.84	8.67	10.58	2.55	0	0	0	0	0	0	6.02
Hickory	2.44	0	0	0	0	0	0	0	0	0	0	0	.56
Yellow birch	0	.92	0	.50	1.38	1.47	0	0	0	0	0	0	.61
Hard maple	2.40	1.96	3.52	4.43	3.80	13.52	0	0	0	0	0	0	3.85
Soft maple	2.01	12.41	0	17.08	29.08	32.99	68.04	0	0	0	0	0	14.87
Beech	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	3.10	4.84	1.67	2.36	13.21	7.14	39.17	0	0	0	0	0	5.49
Balsam poplar	.80	1.17	0	4.53	16.77	35.55	0	74.23	0	0	0	0	6.99
Cottonwood	0	0	0	.49	3.88	0	0	0	0	0	0	0	.91
Paper birch	15.71	18.59	25.17	44.64	79.88	103.53	28.29	82.31	0	0	0	0	42.67
Bigtooth aspen	7.16	10.66	42.93	81.06	159.42	111.12	0	0	0	0	0	0	67.35
Quaking aspen	77.06	158.90	224.50	412.34	511.98	649.86	417.54	73.01	0	0	0	0	314.08
Basswood	.96	5.51	0	1.51	7.90	12.33	0	0	0	0	0	0	3.60
Butternut	0	0	0	0	0	0	0	0	0	0	0	0	0
Black walnut	5.70	1.10	0	10.19	18.48	33.19	0	0	0	0	0	0	9.72
Black cherry	0	0	0	0	0	0	0	0	0	0	0	0	0
Elm	0	0	0	0	0	0	0	0	0	0	0	0	0
Other hardwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Noncommercial spp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	123.34	225.95	314.83	617.21	890.99	1,044.22	632.17	301.96	0	0	0	0	497.63
Total all species	156.87	257.50	373.14	689.63	986.96	1,253.83	963.87	1,029.98	142.79	0	0	0	569.85
Number of plots	116	65	50	137	101	27	4	1	1	1	0	0	503
Standard error	15.16	25.08	31.18	29.33	47.60	87.54	234.58	R	R	I	0	0	21.30
Average basal area	24	45	54	69	84	97	71	71	15	0	0	0	58

[1] See page 21 for definition of forest types and pages 21 and 22 for species group.

Table 16.--*Estimated volume per acre yield from growing-stock trees for the aspen type on sites having site indexes 71 to 80 in Wisconsin by species group and stand age*[1]

(In cubic feet)

Species group	Stand age class (years)											All
	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-120	121+	classes
SOFTWOODS													
White pine	5.07	5.24	4.89	5.05	32.28	37.57	127.75	0	0	310.61	0	67.11	13.29
Red pine	11.57	12.69	9.82	9.15	16.55	50.39	170.58	0	0	85.80	0	0	14.46
Jack pine	0	4.06	12.71	9.90	11.78	0	0	0	0	0	0	0	8.12
White spruce	2.69	1.32	.99	1.15	6.25	0	21.32	0	0	0	0	0	2.40
Black spruce	0	2.90	0	0	.44	0	0	0	0	0	0	22.38	.69
Balsam fir	15.43	5.27	6.77	20.93	17.03	5.26	55.79	0	0	146.72	0	136.64	15.96
Hemlock	1.68	2.22	0	.59	0	0	0	0	0	0	0	0	.73
Tamarack	0	1.12	1.59	.55	1.46	0	0	0	0	0	0	0	.87
Northern white-cedar	9.18	5.02	0	1.07	0	0	23.03	0	0	0	0	0	2.44
Other softwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	45.63	39.83	36.77	48.39	85.78	93.22	398.49	0	0	543.12	0	226.13	58.96
HARDWOODS													
White oak	2.60	6.36	2.56	10.32	15.75	0	0	0	59.60	0	0	0	8.13
Select red oak	4.31	7.02	13.58	35.84	49.37	82.81	0	0	1,157.11	0	0	0	29.69
Other red oak	.88	0	5.91	7.49	5.89	9.95	0	0	0	0	0	0	4.91
Hickory	1.70	.71	0	1.05	0	0	0	82.38	0	0	0	0	1.06
Yellow birch	0	0	0	0	2.72	4.27	0	0	0	0	0	0	.59
Hard maple	0	1.98	2.49	6.53	10.28	6.37	18.80	0	0	0	0	0	5.14
Soft maple	12.46	5.27	19.63	24.25	33.02	60.30	12.40	0	0	0	0	74.99	21.75
Beech	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	2.38	1.31	1.83	9.44	8.25	0	26.33	0	0	0	0	0	5.77
Balsam poplar	0	2.44	6.40	.30	0	0	28.62	156.19	0	0	0	0	2.60
Cottonwood	0	0	0	1.82	0	0	0	0	0	0	0	0	.63
Paper birch	16.04	35.44	40.88	72.53	101.37	146.22	357.61	32.07	0	62.33	0	21.32	65.12
Bigtooth aspen	9.30	15.87	46.34	150.36	253.34	592.54	98.04	645.03	1,067.79	186.63	0	0	129.94
Quaking aspen	110.76	175.75	325.52	565.89	632.56	301.54	675.97	437.69	74.96	141.87	0	269.61	417.61
Basswood	1.19	1.23	3.00	11.55	10.39	11.78	13.68	0	0	0	0	24.31	7.25
Butternut	0	0	0	.86	0	0	0	0	0	0	0	0	.30
Black walnut	6.09	9.48	1.64	11.04	9.52	0	37.35	60.66	0	0	0	0	8.62
Black cherry	0	0	0	0	0	0	0	0	0	0	0	0	0
Elm	0	0	0	0	0	0	0	0	0	0	0	0	0
Other hardwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Noncommercial spp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	167.72	262.86	469.75	909.28	1,132.46	1,215.77	1,268.80	1,414.01	2,359.47	390.83	0	390.24	709.11
Total all species	213.35	302.69	506.53	957.67	1,218.24	1,308.98	1,667.29	1,414.01	2,359.47	933.95	0	616.37	768.07
Number of plots	46	64	66	143	72	11	5	2	1	1	0	3	414
Standard error	27.44	30.52	36.01	40.20	62.66	208.91	368.54	104.95	R	R	0	497.46	28.18
Average basal area	36	50	62	82	97	96	121	113	128	79	0	49	72

[1]See page 21 for definition of forest types and pages 21 and 22 for species group.

Table 17.--*Estimated volume per acre yield from growing-stock trees for the aspen type on sites having site indexes 81 to 90 in Wisconsin by species group and stand age*[1]

(In cubic feet)

Species group	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-120	121+	All classes
	Stand age class (years)												
SOFTWOODS													
White pine	0	0	18.65	1.11	24.20	0	0	0	0	0	0	0	6.89
Red pine	0	0	7.10	9.94	14.68	0	0	0	0	0	0	0	6.94
Jack pine	22.97	5.24	0	0	5.49	0	0	0	0	0	0	0	5.32
White spruce	2.18	4.77	0	9.68	0	0	0	0	0	0	0	0	4.62
Black spruce	0	2.85	0	.80	0	0	0	0	0	0	0	0	.68
Balsam fir	7.28	14.42	23.31	26.97	11.75	0	0	0	0	0	0	0	18.78
Hemlock	0	0	0	0	0	0	0	0	0	0	0	0	0
Tamarack	0	2.48	0	0	16.61	0	0	0	0	0	0	0	2.61
Northern white-cedar	0	0	0	7.04	28.11	0	0	0	0	0	0	0	6.50
Other softwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	32.43	29.76	49.07	55.54	100.84	0	0	0	0	0	0	0	52.35
HARDWOODS													
White oak	0	0	8.13	15.38	26.23	39.73	0	0	0	0	0	0	11.49
Select red oak	2.48	3.39	10.62	65.42	50.69	243.86	0	0	0	0	0	0	38.73
Other red oak	6.59	0	3.58	4.76	26.47	0	0	0	0	0	0	0	7.14
Hickory	0	0	0	0	2.45	0	0	0	0	0	0	0	.34
Yellow birch	3.56	1.97	4.98	3.64	5.30	0	0	0	0	0	0	0	3.79
Hard maple	6.24	0	4.22	9.54	24.01	15.20	0	0	0	0	0	0	8.93
Soft maple	6.93	15.38	16.12	49.38	92.61	0	0	0	0	0	0	0	37.16
Beech	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	2.20	9.26	2.48	15.46	31.75	24.89	0	0	0	0	0	0	12.63
Balsam poplar	12.85	0	0	9.91	0	0	0	0	0	0	0	0	5.88
Cottonwood	0	0	0	0	0	0	0	0	0	0	0	0	0
Paper birch	28.55	21.85	50.38	90.93	67.88	0	0	0	0	0	0	0	59.62
Bigtooth aspen	13.04	42.77	111.70	247.19	541.80	323.49	0	0	0	0	0	0	199.92
Quaking aspen	100.36	173.21	366.26	572.72	559.58	1,075.13	0	0	0	0	0	0	413.35
Basswood	0	0	3.30	0	9.30	0	0	0	0	0	0	0	1.83
Butternut	0	0	0	1.91	6.53	48.10	0	0	0	0	0	0	2.52
Black walnut	12.12	9.38	30.10	4.24	22.28	23.56	0	0	0	0	0	0	13.45
Black cherry	0	0	0	0	0	0	0	0	0	0	0	0	0
Elm	0	0	0	0	0	0	0	0	0	0	0	0	0
Other hardwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Noncommercial spp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	194.91	277.23	611.87	1,090.47	1,466.87	1,793.95	0	0	0	0	0	0	816.79
Total all species	227.34	306.99	660.93	1,146.01	1,567.70	1,793.95	0	0	0	0	0	0	869.14
Number of plots	27	21	27	60	22	3	0	0	0	0	0	0	160
Standard error	31.60	44.54	77.65	56.93	120.98	676.51	0	0	0	0	0	0	49.99
Average basal area	37	63	68	91	109	98	0	0	0	0	0	0	77

[1]See page 21 for definition of forest types and pages 21 and 22 for species group.

Table 18.--*Estimated volume per acre yield from growing-stock trees for the aspen type on sites having site indexes 91 to 100 in Wisconsin by species group and stand age*[1]

(In cubic feet)

Species group	Stand age class (years) 0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-120	121+	All classes
SOFTWOODS													
White pine	0	0	4.81	0	0	0	0	0	0	0	0	0	1.56
Red pine	0	0	0	0	37.15	0	0	0	0	0	0	0	5.46
Jack pine	0	12.08	0	0	0	0	0	0	0	0	0	0	1.78
White spruce	0	0	0	0	0	0	0	0	0	0	0	0	0
Black spruce	0	0	0	0	0	0	0	0	0	0	0	0	0
Balsam fir	0	0	0	25.23	0	0	0	0	0	0	0	0	5.94
Hemlock	0	0	0	0	0	0	0	0	0	0	0	0	0
Tamarack	0	0	0	0	0	0	0	0	0	0	0	0	0
Northern white-cedar	0	0	0	0	0	0	0	0	0	0	0	0	0
Other softwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	12.08	4.81	25.23	37.15	0	0	0	0	0	0	0	14.73
HARDWOODS													
White oak	0	21.53	23.14	33.25	50.58	0	0	0	0	0	0	0	25.91
Select red oak	12.77	0	0	58.63	226.42	0	0	0	0	0	0	0	48.97
Other red oak	0	10.95	11.13	25.24	0	0	0	0	0	0	0	0	11.15
Hickory	0	0	0	23.57	0	0	0	0	0	0	0	0	5.55
Yellow birch	0	7.02	0	0	24.51	0	0	0	0	0	0	0	4.64
Hard maple	0	0	0	0	0	0	0	0	0	0	0	0	0
Soft maple	22.92	0	10.49	8.21	11.06	0	0	0	0	0	0	0	10.32
Beech	0	0	0	0	0	0	0	0	0	0	0	0	0
Ash	0	0	29.20	30.82	68.58	0	0	0	0	0	0	0	26.78
Balsam poplar	0	0	0	0	61.46	0	0	0	0	0	0	0	9.04
Cottonwood	0	0	0	0	0	0	0	0	0	0	0	0	0
Paper birch	0	12.50	38.57	125.98	96.57	0	0	0	0	0	0	0	58.16
Bigtooth aspen	25.06	0	71.72	410.52	781.37	0	0	0	0	0	0	0	238.39
Quaking aspen	162.02	177.69	631.33	416.80	167.61	0	0	0	0	0	0	0	376.93
Basswood	0	0	0	16.91	0	0	0	0	0	0	0	0	3.98
Butternut	0	0	3.60	0	0	0	0	0	0	0	0	0	1.17
Black walnut	13.19	0	20.34	7.79	104.84	0	0	0	0	0	0	0	25.77
Black cherry	0	0	0	0	0	0	0	0	0	0	0	0	0
Elm	0	0	0	0	0	0	0	0	0	0	0	0	0
Other hardwoods	0	0	0	0	0	0	0	0	0	0	0	0	0
Noncommercial spp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	235.96	229.69	839.51	1,157.71	1,593.00	0	0	0	0	0	0	0	846.75
Total all species	235.96	241.77	844.32	1,182.94	1,630.15	0	0	0	0	0	0	0	861.48
Number of plots	5	5	11	8	5	0	0	0	0	0	0	0	34
Standard error	126.41	72.67	112.06	194.19	233.89	0	0	0	0	0	0	0	106.28
Average basal area	26	56	80	101	108	0	0	0	0	0	0	0	77

[1]See page21 for definition of forest types and pages 21 and 22 for species group.

APPENDIX I.--FOREST TYPES

A classification of forest land based upon the species forming a plurality of live-tree stocking. Major forest types in Wisconsin are:

Jack pine.--Forests in which pine species comprise a plurality of the live tree stocking, with jack pine the most common. (Common associates include aspen, white birch, maple, balsam fir, cherry, and oak.)

Red pine.--Forests in which pine species comprise a plurality of the live-tree stocking, with red pine the most common. (Common associates include aspen, white birch, maple, balsam fir, and red oak.)

White pine.--Forests in which pine species comprise a plurality of the live-tree stocking, with eastern white pine the most common. (Common associates include hemlock, aspen, white and yellow birch, and maple.)

Balsam fir-white spruce.--Forests in which balsam fir or white spruce, singly or in combination, comprise a plurality of the live-tree stocking. (Common associates include white-cedar, black spruce, tamarack, maple, birch, hemlock, and aspen.)

Black spruce.--Forests in which swamp conifers (black spruce, tamarack, and northern white-cedar) comprise a plurality of the live-tree stocking, with black spruce the most common.

Northern white-cedar.--Forests in which swamp conifers comprise a plurality of live-tree stocking, with northern white-cedar the most common.

Tamarack.--Forests in which swamp conifers comprise a plurality of live-tree stocking, with tamarack the most common.

Oak-hickory.--Forests in which upland oaks or hickories, singly or in combination, comprise a plurality of the live-tree stocking. (Common associates include aspen, cherry, balsam fir, elm, maple, and white birch.)

Elm-ash-cottonwood.--Forests in which lowland elm, ash, or cottonwood, singly or in combination, comprise a plurality of the live-tree stocking. (Common associates include maple, basswood, and river birch.) These forests may be subtyped cottonwood when it is the most common species.

Maple-beech-birch.--Forests in which maple, beech, yellow birch, or upland elm, singly or in combination, comprise a plurality of the live-tree stocking. (Common associates include hemlock, elm, basswood, white pine, and white and yellow birch.) Locally this type is called "northern hardwoods."

Aspen.--Forests in which a mixture of quaking or bigtooth aspen, or balsam poplar, singly or in combination, comprise a plurality of the live-tree stocking. (Common associates include maple, white birch, balsam fir, red and northern pin oak, and cherry.)

Paper birch.--Forests in which paper birch comprises a plurality of the live-tree stocking. (Common associates include aspen, maple, balsam fir, red and northern pin oak, and cherry.)

APPENDIX II. SPECIES GROUPS

SOFTWOODS

Species Group	Scientific Name
White pine	*Pinus strobus*
Red pine	*Pinus resinosa*
Jack pine	*Pinus banksiana*
White spruce	*Picea glauca*
Black spruce	*Picea mariana*
Balsam fir	*Abies balsamea* var. *balsamea*
Hemlock	*Tsuga canadensis*
Tamarack	*Larix laricina*
Northern white-cedar	*Thuja occidentalis*
Other softwoods	*Juniperus virginiana* *Pinus sylvestris* All other softwoods

HARDWOODS

White oak	*Quercus alba* *Quercus bicolor* *Quercus macrocarpa* *Quercus muehlenbergii*

Species Group	Scientific Name
Select red oak	*Quercus rubra*
Other red oak	*Quercus palustris*
	Quercus velutina
Hickory	*Carya cordiformis*
	Carya ovata
	Carya tomentosa
Yellow birch	*Betula alleghaniensis*
Hard maple	*Acer nigrum*
	Acer sacchrum
Soft maple	*Acer rubrum* var. *rubrum*
	Acer saccharinum
Beech	*Fagus grandifolia*
Ash	*Fraxinus americana*
	Fraxinus nigra
	Fraxinus pennslvanica
Balsam poplar	*Populus balsamifera*
Cottonwood	*Populus deltoides*
Paper birch	*Betula nigra*
	Betula papyrifera var. *papyrifera*
Bigtooth aspen	*Populus grandident*
Quaking aspen	*Populus tremuloide*
Basswood	*Tilia americana*
Butternut	*Juglans cinerea*
Black walnut	*Juglans nigra*
Black cherry	*Prunus serotina*
Elm	*Ulmus americana*
	Ulmus rubra
	Ulmus thomasii
Other hardwoods	*Acer negundo*
	Celtis occindental
	Gleditsia triacant
	Nyssa sylvatica var. *sylvatica*
	Platanus occidenta
	All other hardwoo
Noncommercial species	

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Forest type	Unit I (Northeastern)	Unit II (Northwestern)	Unit III (Central)	Unit IV (Southwestern)	Unit V (Southeastern)	Statewide
Jack pine	1	13	25	37	NA	55
Red pine	2	14	26	38	45	56
White pine	3	15	27	39	46	57
Balsam fir-White spruce	4	16	28	NA[1]	47	58
Black spruce	5	17	29	NA	NA	59
Northern white-cedar	6	18	30	NA	48	60
Tamarack	7	19	31	NA	49	61
Oak-Hickory	8	20	32	40	50	62
Elm-Ash-Cottonwood	9	21	33	41	51	63
Maple-Beech-Birch	10	22	34	42	52	64
Aspen	11	23	35	43	53	65
Paper birch	12	24	36	44	54	66

See page 21 for definition of forest types and figure 1 for boundaries of Forest Survey Units. Then circle numbers for table sets desired and return this order blank to: PUBLICATIONS, North Central Forest Experiment Station, Folwell Avenue, St. Paul, Minnesota 55108.

[1]NA = not available.

Essex, Burton L., and Jerold T. Hahn.
1976. Empirical yield tables for Wisconsin. USDA For. Serv. Gen. Tech. Rep. NC-25, 22 p., illus. North Cent. For. Exp. Stn., St. Paul, Minn.

Describes the tables derived from the 1968 forest survey of Wisconsin. These tables are broken down according to Wisconsin's 5 Forest Survey Units, 12 forest types, and 5 site index classes. Presents 18 tables as examples of the more than 500 that can be ordered by using the order form enclosed in the publication.

OXFORD: 524.37:(775). KEY WORDS: inventory, volume, growth.

Essex, Burton L., and Jerold T. Hahn.
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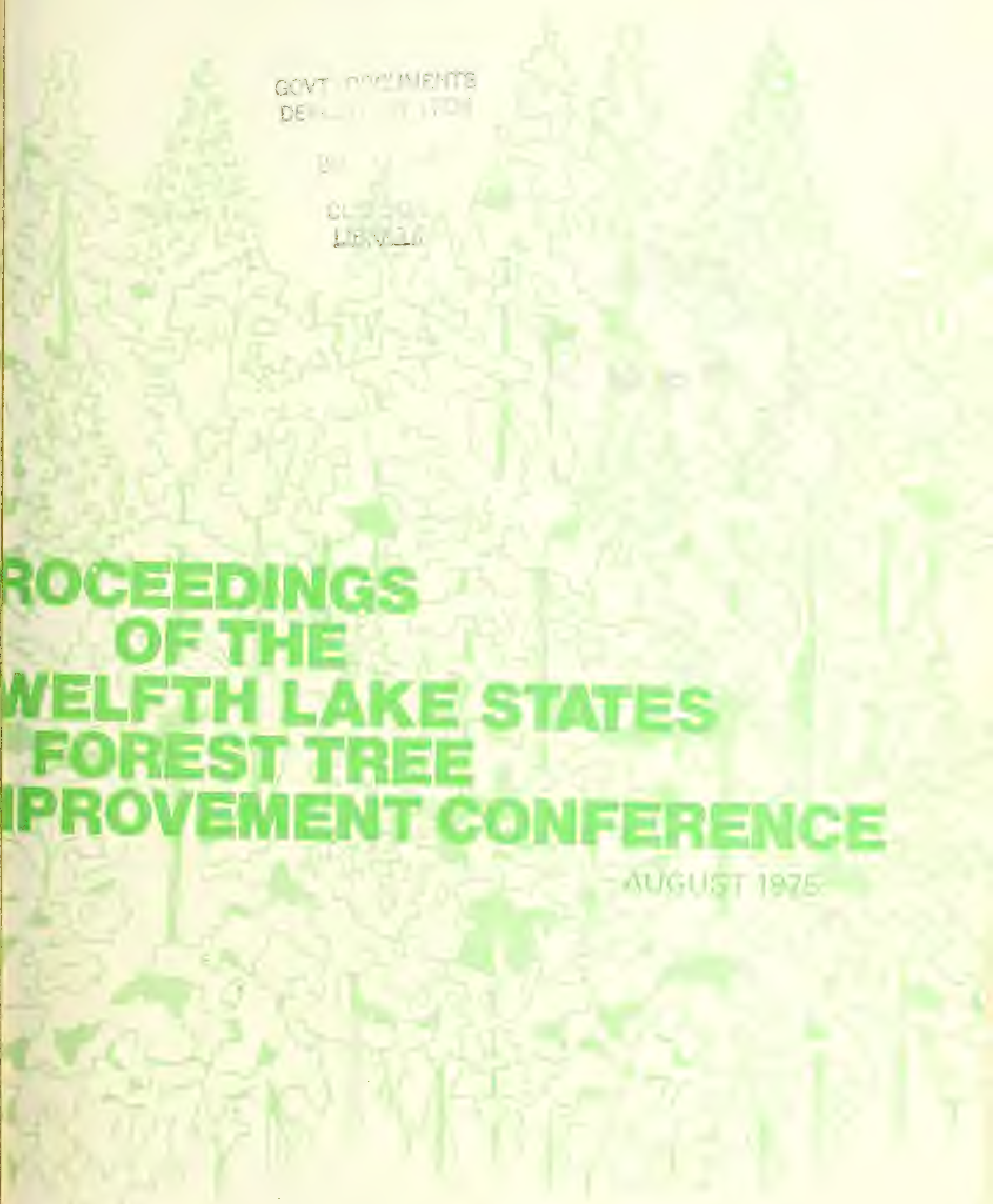

ROCEEDINGS OF THE WELFTH LAKE STATES FOREST TREE IPROVEMENT CONFERENCE

AUGUST 1975

H CENTRAL FOREST EXPERIMENT STATION
ST SERVICE U.S. DEPARTMENT OF AGRICULTURE

ACKNOWLEDGMENTS

Eleventh Lake States Forest Tree Improvement Conference

The Eleventh Lake States Forest Tree Improvement Conference was held October 10 to 12, 1973, at Kellogg Biological Station, Hickory Corners, Michigan. The meeting was devoted entirely to visits to the many field tests of the Department of Forestry, Michigan State University, at Kellogg Forest. The Lake States Forest Tree Improvement Committee wants to express its gratitude to the University staff for an excellent meeting.

Because it was a field meeting, NO PROCEEDINGS WERE ISSUED FOR THE ELEVENTH LAKE STATES FOREST TREE IMPROVEMENT CONFERENCE.

Twelfth Lake States Forest Tree Improvement Conference

The Twelfth Lake States Forest Tree Improvement Conference was held jointly with the Canadian Tree Improvement Association from August 18 to 22, 1975, at Petawawa Forest Experiment Station, Chalk River, Ontario. Thanks to excellent planning it was a highly successful meeting. The Lake States Forest Tree Improvement Committee wishes to thank the Canadian Tree Improvement Association and the Petawawa Forest Experiment Station of the Canadian Forestry Service for this outstanding opportunity for scientific exchange. The abstracts from the Canadian Tree Improvement Association Seminar (Apply Genetics in Forest Management) are included in this volume. Complete text will be published in Proceedings of the Fifteenth Meeting of the Canadian Tree Improvement Association, Part 2.

Dean W. Einspahr, *Chairman,*
Lake States Forest Tree
Improvement Committee

North Central Forest Experiment Station
John H. Ohman, Director
Forest Service - U.S. Department of Agriculture
Folwell Avenue
St. Paul, Minnesota 55108

1976

PROCEEDINGS OF THE TWELFTH LAKES STATES FOREST TREE IMPROVEMENT CONFERENCE

AUGUST 1975

CONTENTS PAGE

Forest Tree Improvement Program for the National Forests in the Lake States
R. G. Miller and J. D. Murphy 1

White Pine Pollen Species and Year Do Not Affect Conelet Drop or Cone Size in *Pinus strobus*
H. B. Kriebel 10

Jack Pine Seedling Seed Orchard Establishment and Projected Seed Yields
Richard M. Jeffers. 16

Controlled Pollination in Eastern Redcedar and Rocky Mountain Juniper
Gilbert H. Fechner. 24

Geographic Variation of Growth and Wood Properties in Japanese Larch in Southwestern Lower Michigan
Chen Hui Lee. 35

Ten-Year Performance of Douglas-Fir Provenances in Eastern Nebraska
Ralph A. Read and John A. Sprackling. 47

Improved Strains of Douglas-Fir for the Northeastern United States
Donald H. DeHayes and Jonathan W. Wright. 64

Provenance and Family Variation in Balsam Fir from Michigan and Wisconsin
D. T. Lester, R. M. Jeffers, and J. W. Wright 74

Eastern White Pine Seed Source Variation in the Northeastern United States: 16-Year Results
Maurice E. Demeritt, Jr., and Harry C. Kettlewood 80

Stand, Family, and Site Effects in Upper Ottawa Valley White Spruce
N. K. Dhir 88

A White Spruce Progeny Test--Seedling Seed Orchard: 12th Year Progress Report
C. A. Mohn, D. E. Riemenschneider, W. Cromell, and L. C. Peterson 98

Report on the Cross Pinus resionsa X P. tropicalis
Richard B. Hall, David F. Karnosky, and Donald P. Fowler . . . 108

Genetic Variation in the Height-Diameter Ratio in Scotch Pine
Jonathan W. Wright 113

Selection and Breeding Eastern Cottonwood for Resistance to Foliage Diseases
J. J. Jokela and W. R. Lovett. 122

Genetic Control of Resistance to Hypoxylon Infection and Canker Development in Populus tremuloides
Frederick A. Valentine, Paul D. Manion and Kathleen E. Moore . 132

Nuclear Proteins of Dry and Germinating Conifer Seeds
J. A. Pitel and D. J. Durzan 147

The Potential for Cloning White Spruce Via Tissue Culture
Robert A. Campbell and Donald J. Durzan. 158

The Clonal Test: An Aid to Progeny Testing and a Way to Speed up Genetic Gains
Armand G. Corriveau. 167

Prescription for the Aerial Environment of a Plastic Greenhouse Nursery
D. F. W. Pollard and K. T. Logan 181

Management of Tree Growth and Research Plantations
Donald A. Fraser 192

Canadian Tree Improvement Association Abstracts from the Fifteenth Meeting. 202

FOREST TREE IMPROVEMENT PROGRAM FOR THE NATIONAL FORESTS IN THE LAKE STATES

R. G. Miller and J. D. Murphy 1/

ABSTRACT.--The Eastern Region of the USDA Forest Service has been conducting a Forest Tree Improvement Program on the national forests in the Lake States since the early 1960's. This paper presents a general review of the program, including objectives, organization, species priorities, and basic steps and procedures. Also discusses accomplishments and future plans.

A tree improvement program for the more than 5.6 million acres of commercial forest land on the eight national forests in the Lake States was begun in the early 1960's. Objectives for the program are: (1) to develop an aggressive, practical tree improvement program; (2) to produce seed for seedling production and/or direct seeding that will yield fast-growing, high-quality, pest-resistant forest trees; and (3) to develop and demonstrate cultural methods for producing timber and other products by applying sound genetic principles.

The program is carried on by a Regional Geneticist, a Zone Geneticist; in addition each forest has one or more technicians. The Regional Geneticist develops and coordinates the tree improvement, nursery, and seed procurement programs. The Zone Geneticist implements and coordinates the tree improvement program which includes training and supervising a full-time seed orchard manager, training technicians for each national forest, and keeping all personnel informed of progress and status of the tree improvement program. The technicians perform the initial screening of superior tree selections, do the seed and scion collection work, and assist in collecting data and maintaining records.

SPECIES

The first step in the program was to establish species priorities and program intensities. Factors considered included acres of commercial forest land in the various timber types, genetic variation within the species, plantability of the species, current research programs, estimated

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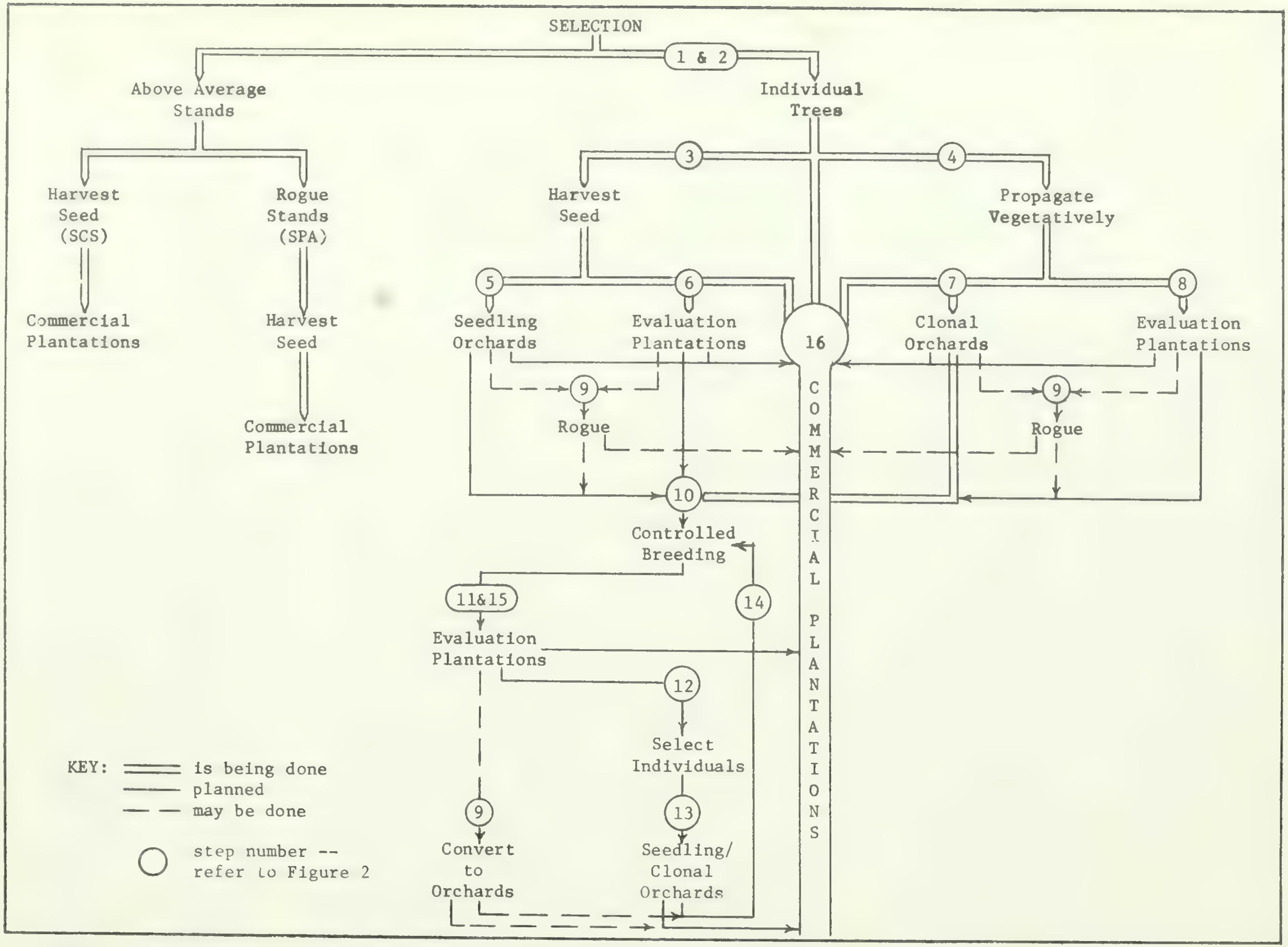

Figure 1.--Basic steps in the Region 9 forest tree improvement program.

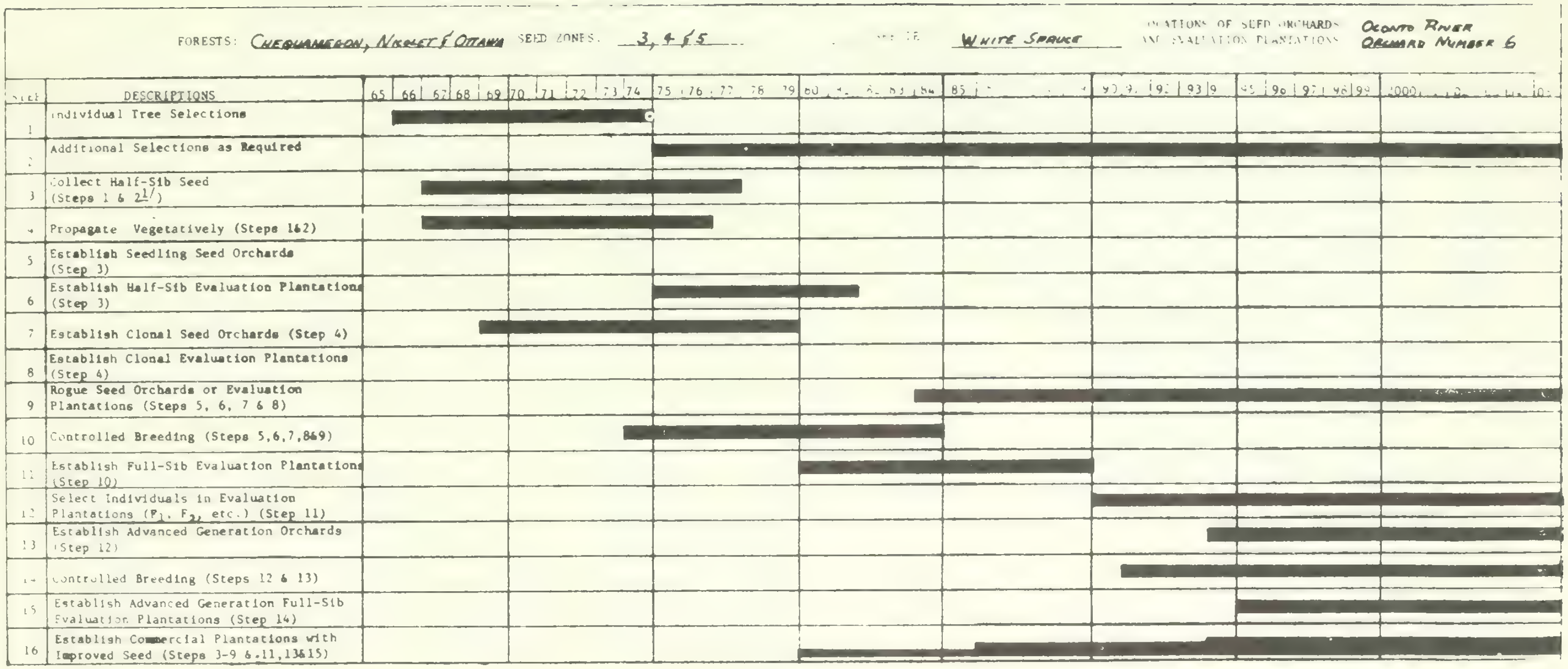

Figure 2.--Region 9 forest tree improvement time schedule for white spruce on the Chequamegon, Nicolet and Ottawa National Forests. The schedule indicates the time span for those steps applicable to the intensity of the program. (1/ The numbers in parenthesis refer to previous steps that this action is dependent on.)

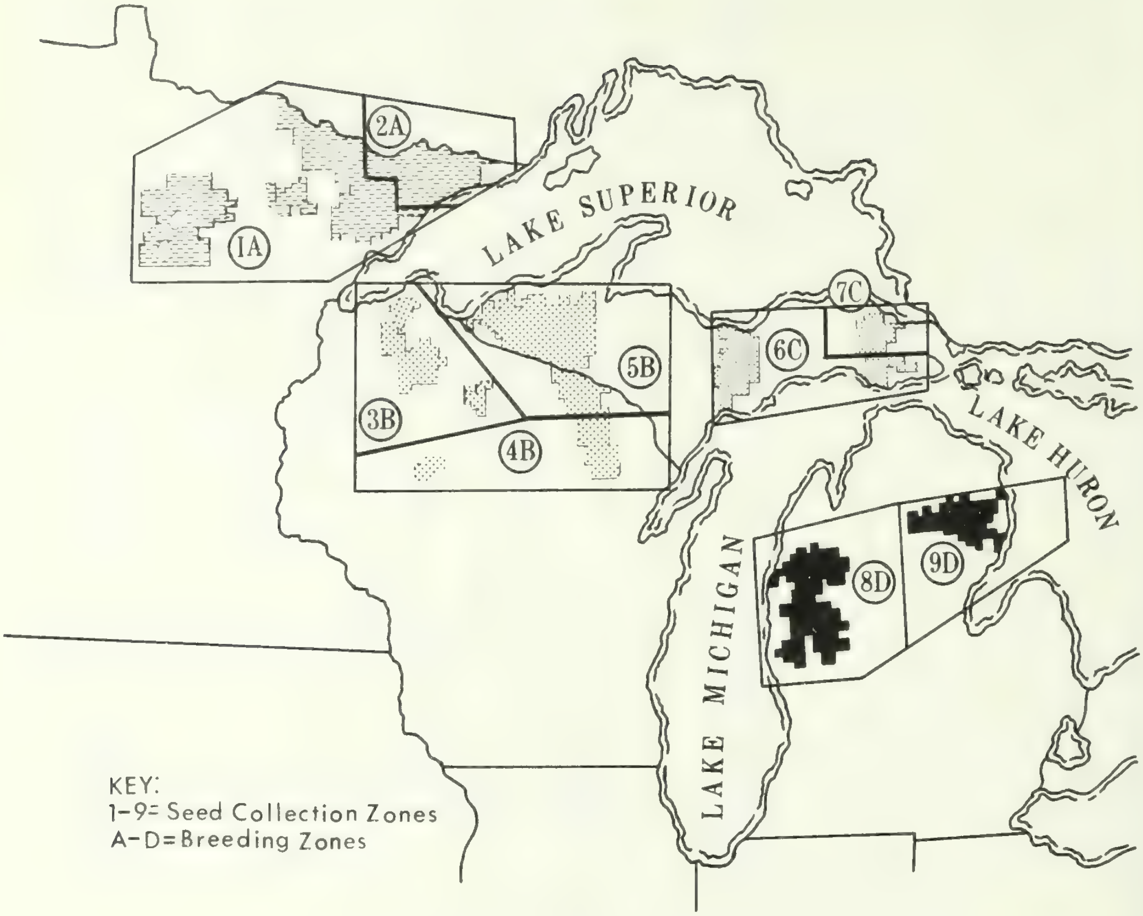

Figure 3.--Seed collection zones and breeding zones.

economic gains, and, to some extent, development programs carried on by others (table 1).

Table 1.--Species priority and types of programs

Species (in order of priority)	Priority group	SCS and SPA	Selection	Seed orchard	Breeding	Evaluation plantation
		Program				
White Pine	A		X	X	X	X
White Spruce	A	X	X	X	X	X
Aspen	A					X
Jack Pine	A	X	X	X	X	X
Black Spruce	A	X	X	X	X	X
Red Pine	A	X	X	X	X	X
Yellow Birch	A		X	X	X	X
Paper Birch	B		X			X
Black Cherry	B		X			X
Sugar Maple	B		X			X
Red Oak	C		X			X
Basswood	C		X			X
Red Maple	C		X			X
Larch	C		X			X

The program has been divided into 16 basic steps (fig. 1). The program for each species varies considerably in scope and degree. Time schedules are used to show the anticipated work for each species and to coordinate the work that involves several species over a period of years. The schedule for white spruce (fig. 2) is one of the most involved.

SEED COLLECTION ZONES AND BREEDING ZONES

The second major action in the program was to delineate seed collection zones for the eight national forests (fig. 3). The zones are based on the average January temperature and the total number of degree days above 50°F during the growing season (Rudolf 1956). To simplify the establishment of the seed orchards, the nine seed collection zones have been combined into four breeding zones (fig. 3). These breeding zones are based on the desired adaptability of the improved materials and may have to be modified as data become available from evaluation plantations.

SEED COLLECTION

Seed collection stands (SCS) have been located for black spruce and red pine within each seed collection zone. Timber sales within these selected stands are coordinated with good seed crops, and cones are

collected from the downed tops. White spruce and red pine seed production areas (SPA) were established in each seed zone where the species occurred naturally. Cones have been collected in the white spruce SPA's during good crop years by shooting or cutting the tops out of selected trees and picking the cones off the tops on the ground. The trees usually produce four to six new tops and another bumper cone crop within 6 years. Nienstaedt 2/ has included white spruce seed collected from one of the SPA's in his research and found that the SPA seedlings were 10 percent taller than the control seedlot at age 4. Small amounts of seed have been harvested in the red pine SPA's, mainly by climbing the trees. Collecting red pine cones in SPA's has been more difficult and expensive than similar work in white spruce SPA's. The time is rapidly approaching when all seed used on national forest land will originate from SCS, SPA, or individual tree collections.

SELECTION

Individual trees exhibiting fast growth, good form, and pest resistance are located on each national forest by trained technicians. Comparison trees are used to guide selection. Although there are inherent weaknesses in this process, comparison trees do provide a guide for the initial phases of the selection work (Ledig 1974). As workers become more familiar with the selection process, they depend less on comparison trees and more on how the candidate compares with previous selections. Several outstanding trees have been included in the program based on their own merit. More than 2,000 selections representing 11 species have been made.

VEGETATIVE PROPAGATION

All grafts are made at the J. W. Toumey Nursery, Watersmeet, Michigan, or at the Oconto River Seed Orchard. The scion collection work during January and February is closely coordinated with the grafting operation, enabling the grafting of all scions within 7 days of collection. The completed grafts are removed from their pots and lined out at the nursery or seed orchard after the danger of frost is past. The grafts are cared for from 1 to 3 years, depending on the species, and then moved to their specific seed orchard. Between 1969 and 1973, grafting success averaged 87 percent for white pine, 74 percent for white spruce, 81 percent for black spruce, and 83 percent for yellow birch. During the past 2 years, secondary scions have been collected from established grafts growing in the seed orchard. There has been no problem with graft incompatibility.

SEED ORCHARD

In 1967, we consolidated all seed orchards for the Lake States national forests in one area called the Oconto River Seed Orchard, about 30 miles

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east of Antigo, Wisconsin on the Nicolet National Forest. This made it possible to employ and train a crew, as well as purchase the necessary equipment and supplies to intensively manage the seed orchard. The area includes 500 acres of cultivated farmland, 180 acres of woodland, a pond, and a trout stream.

During the summer of 1968, a survey crew established a grid system and constructed a topographic map using a 1-foot contour interval. Soil pits were dug adjacent to several grid stakes, and soil types were plotted on the topographic map. The soil in the cultivated fields is mostly Antigo silt loam, deep and shallow phases. This is an excellent agricultural soil and no fertilization was recommended for tree species at the time. A deer exclosure fence was erected around the entire section in the summer of 1969. The administrative site, including warehouse, office, headhouse, and greenhouse, was developed between 1970 and 1974. The warehouse also serves as an inoculation chamber for the blister rust-resistant eastern white pine program.

Pollen contamination among seed orchards of a particular species is reduced by locating the individual orchards far apart and by planting orchards of other species between them. The wooded areas, composed mainly of aspen, maple, and balsam fir, also serve to reduce pollen contamination.

The first seed orchards were established on cultivated fields during the spring of 1969. A computer program developed by Stairs et al. at the University of Wisconsin was used to generate a completely random planting design that maximizes out-crossing. The grafts are planted, staggered 30 feet apart in rows 15 feet apart--an actual spacing of about 22 feet by 22 feet. The initial orchards were kept clean-cultivated for about 3 years, and the grass was mowed around several extra grafts that were planted at a 10 feet by 10 feet spacing. Because the cone production on clones (white pine and white spruce) growing in both mowed and cultivated seed orchards seemed to be about the same, cultivation was reduced and the orchards were seeded to grass. Now the grafts are planted in the sod, the area around each graft is treated with an herbicide, and a mulch of sawdust or other suitable material is placed around the grafts. This method has increased accessibility within the orchards, reduced maintenance costs, and maintained excellent survival and growth.

Cone production in the white and black spruce and white pine orchards has been increasing each year. In 1974 it ranged from 18 to 31 percent of the total number of grafts in two white pine orchards, from 12 to 55 percent in white spruce and from 2 to 41 percent in black spruce. White pine and black spruce produced no male strobili. Most of the seed collected in the orchards is being reserved for establishing evaluation plantations.

The eastern white pine blister rust-resistant development program is also centered at the Oconto River Seed Orchard (Miller 1972).

EVALUATION PLANTATIONS

The evaluation plantations, like the seed orchards, are being consolidated as much as possible to facilitate the work and ensure proper care. Five major evaluation sites have been selected--one in Minnesota, Upper Michigan, and Lower Michigan, and two in Wisconsin.

Efforts have been concentrated on producing and evaluating full-sib material, but half-sib evaluation plantations are planned for white spruce, black spruce, and jack pine. Whenever possible, plant materials will be evaluated in each of the five major evaluation plantation sites. One objective is to identify material that will perform well in several of the sites. Seedlots that produced these selected materials would be sown in the nursery each year as a small part of the normal production and used within appropriate zones where stock shortages exist.

CONTROLLED POLLINATION

After reviewing several mating designs, it was decided to use a multiple four-parent disconnected half diallel (Squillace 1973). This design provides great flexibility in making crosses within and among the seed orchards for specific zones, with the production of a minimum number of half-sib families. In order to broaden the genetic base of the breeding program, the program was developed in cooperation with the North Central Forest Experiment Station, Institute of Forest Genetics, and will include their selections. This design was used in the white spruce breeding program, which began in the spring of 1975.

Evaluation plantations will be established as the full-sib seed becomes available from a sufficient number of crosses. As soon as the trees begin to flower, selections will be made in these plantation and used to upgrade existing orchards and/or establish new ones, and will also be included in an advanced generation breeding program. The main objective will be to create new generations as rapidly as possible with the available material and data. The older plantations will continue to be evaluated and new selections added to, or previous selections eliminated from, the breeding programs and seed orcahrds. This will result in a continuous genetic gain in the seed orchards.

RECORDS

An ADP system has been developed to help maintain the identity and status of all plant material used in the tree improvement program. The system also summarizes and analyzes the data collected in seed orchards, evaluation plantations, and breeding programs.

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WHITE PINE POLLEN SPECIES AND YEAR DO NOT AFFECT CONELET DROP OR CONE SIZE IN *PINUS STROBUS*

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ABSTRACT--Statistical analysis of 6 years' breeding experiments on *Pinus strobus* L. showed that conelet drop was controlled by female parent but not by white pine pollen species or year of pollination. Crossing with a species never yielding viable seed did not increase conelet drop. The degree of loss was the same after self- and open-pollination as it was after controlled crossing. The length and weight of mature cones also depended only on female parent. A possible relation is suggested in pines between the presence or absence of a pollen effect on cone retention and the type of crossability barrier.

Premature cone drop in pines is a widespread and serious problem in many species. It is especially frequent in the first part of the conelet stage, i.e., early in the first year of cone development.

Abscission of conelets during the first few weeks after pollination may result from severe competition with vigorously growing vegetative shoots for photosynthates and mineral nutrients (Sweet and Bollman 1970). It also appears to be associated with a threshhold proportion of aborted ovules per cone (Burdon and Low 1973b).

In regions where pollen supply is limited, wind pollination may be insufficient for cone retention. If most of the ovules are not pollinated, they collapse in a few days and the conelet drops off (Sarvas 1962).

Cone losses due to wind, animals, birds, and insects may occur at any time during cone development but are most common at later stages, expecially during the second year.

The degree of maternal control over conelet drop varies among individu[...] Clonal tests of *Pinus sylvestris* L. have shown that trees vary widely in the amount of pollen required to retain conelets (Brown 1970). Clonal variation in conelet drop in *Pinus radiata* D. Don, where pollen supply is not a proble[...]

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may be due to clonal differences in spring growth patterns because of the critical competition with vegetative growth (Sweet and Bollman 1970).

The pollen parent had no effect on conelet drop in intraspecific crosses of Pinus resinosa Ait. (Fowler 1965b). In Hagman's crosses between species and between subgenera of pines, there was no effect in crosses of Pinus peuce Griseb. and Pinus cembra L. with other white pines, regardless of crossability. A pollen parent effect was apparent, however, in crosses of these pines with hard pines. In P. sylvestris, the male effect varied from nil to high in species crosses within the hard pines and was pronounced in crosses with white pines.[2]

Conelet drop is a serious problem in P. strobus. In Ohio, heavy losses occur during the first 4 weeks after pollination. Records suggest that there were differences in conelet drop among trees used in breeding experiments in Ohio. This led to analysis of crossing records to estimate male and female parental effects as an aid in the selection of breeding materials. The availability of 6 years' data permitted analysis of the possible effect of year of pollination as an indication of nongenetic effects.

METHODS

Crossing Technique

Crosses were made in young stands and plantations of P. strobus in north central Ohio. They included selfs, P. strobus crosses, and crosses with other white pines. Standard pollination procedures were used with adequate precautions for protection from contamination. For each cross combination, records were kept of the pollen parent, number of strobili pollinated, number of conelets bagged for insect protection, and number of cones collected at maturity. Yield of filled and empty seed was recorded. Lengths and weights of cones from 4 years' collections were measured after air-drying and seed extraction.

Analysis

Analysis of conelet drop in interspecific crosses followed the procedure in the generalized least squares program for partial regression developed by Barr and Goodnight (1971). An analysis of variance was run on cone yield data per tree x tree combination for the 6 years 1962, 1963, 1964, 1965, 1966, and 1969 in relation to the number of strobili pollinated. Estimates of the effects of year, male species, and female tree were obtained. Because of the large number of levels involved, the individual male parent effect was excluded from the analysis. This effect, if any existed, would be smaller than the effect of pollen species. If pollen species were nonsignificant, the individual male parent could

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[2] Personal communication with M. Hagman.

therefore be assumed to have no significant effect on conelet drop.

Comparisons of the effects of selfing vs. outcrossing and of controlled vs. open pollination on cone yield per flower were made by "t" tests of trees on which both types of cross were made.

Estimates of the effects of year, pollen species, individual pollen parent, and female tree on cone length and cone weight were also obtained from a least squares analysis of variance. The analysis was based on the mean of each tree x tree combination for all crosses made from 1962 through 1965.

The effects of selfing vs. outcrossing and of controlled vs. open-pollination on cone length and weight were compared by "t" tests.

RESULTS

Mean cone yield, cone length, and cone weight are summarized in table 1 by species cross. Analysis by tree combination showed:

1. Conelet drop was strongly controlled by the individual female parent (p of a larger F = 0.0001).

2. Pollen parent had no significant effect on conelet drop even when it was another species of white pine, either crossable or noncrossable in terms of sound seed yield.

3. Neither selfing nor open pollination affected conelet drop in comparison with controlled intraspecific cross-pollination.

4. Year of pollination had no effect on conelet drop when adjusted for male and female parent.

5. There was no effect of pollen species, pollen parent, year, selfing, or open pollination on length or weight of dry mature cones.

DISCUSSION

Biological Relations

The absence of a pollen parent effect on conelet drop in P. strobus is typical of at least two other white pines, as previously noted. A negligible pollen parent effect on cone length has also been observed in other pines (Fowler 1965a, Burdon and Low 1973a).

The accumulated evidence from these experiments and others covers a diversity of species and suggests that there is a common factor in

the pollen of white pines favoring cone retention, cone scale development, and seed coat formation.

Table 1.--Cone yield, cone length and weight, and sound seed yield of *P. strobus*

INTERSPECIFIC CROSSES						
Cross combination	Female parents	Strobili pollinated	Mean cone yield 1/	Mean dry cone length	Mean dry cone weight 1/	Mean sound seeds per cone
	No.	No.	Percent	cm	gm	No.
P. strobus x						
griffithii	15	1,067	21	10.6	7.9	9.4
monticola	14	3,619	21	9.0	5.4	4.4
peuce	17	2,572	19	8.4	5.4	1.7
peuce x *strobus*	5	334	19	10.4	6.8	.5
parviflora	9	360	18	9.5	5.9	6.8
flexilis	10	1,056	23	9.4	5.8	.0
albicaulis	2	343	05	10.0	5.8	.0
cembra	10	879	15	12.0	7.3	.0
koraiensis	4	274	11	2/	2/	.0
INTRASPECIFIC CROSSES						
P. strobus x						
strobus outcross	41	10,464	19	9.4	6.3	19.3
strobus open	9	438	20	9.6	6.8	19.6
strobus self	17	911	19	9.4	5.9	11.5

1/ Differences nonsignificant at $p = 0.05$ (see Methods).
2/ No measurements taken.

Diffusible pollen-wall enzymes appear to play a role in pollen-tube nutrition and growth (Stanley and Linskens 1965, Knox and Heslop-Harrison 1970) and might be involved in cone nutrition. Genetic factors in pollen controlling the production of sugars and critical to ovule development may function in the nucellar tissue (Hagman 1975) but in at least some species, e.g., *Pinus thunbergiana* Franco, pollen viability is not a requirement for conelet retention (Katsuta 1971).

White pines seem to have embryo inviability as an isolation mechanism (Hagman and Mikkola 1963, Kriebel 1972). It is possible that

a common pollen factor in these pines initially induces cone scale development and later stimulates pollen tube growth and fertilization. Subsequent control is through genome interaction, leading either to full seed formation or embryo abortion, depending on the species combination.

In contrast, incompatibility with arrested pollen tube growth is the typical reproductive barrier in P. sylvestris and other hard pines investigated (McWilliam 1959, Vidaković and Jurković-Bevilacqua 1970). Hagman found that P. sylvestris, unlike the soft pines, has a higher rate of conelet drop in inter- or intra-sectional crosses than in crosses within the species. Clearly, some pollen stimulus to cone retention occurs in P. sylvestris, because all the cones in incompatible species crosses do not abort, but the effect on the strobilus is insufficient for full pollen tube growth and fertilization. All hard pines may not have male-induced conelet drop, but it is evident that they do not share a pollen factor favoring cone retention in interspecific crosses.

The finding that conelet drop was no higher in P. strobus after selfing than after outcrossing agrees with results of other selfing experiments on both soft and hard pines. Pollen-tube incompatibility has never been observed in either subgenus of pines in response to self-pollination (Hagman 1964, 1975). The reaction to selfing occurs after fertilization. Therefore, the results of selfing P. strobus tend to support the suggested relation between post-fertilization ovule abortion and polen-induced cone retention in inviable crosses.

Practical Implications

From the standpoint of the breeder or silviculturist, the dominant female influence on conelet drop in P. strobus implies that individual tree selection for cone retention is of critical importance, especially for seed orchards. Past performance is a good indication of future cone yield. This criterion must, of course, be integrated into the overall selection index and not made at the expense of desirable tree characteristics.

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JACK PINE SEEDLING SEED ORCHARD ESTABLISHMENT AND PROJECTED SEED YIELDS

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ABSTRACT.--Jack pine test plantings of open pollinated progenies from proven seed sources can be converted to seedling seed orchards. A combined selection index based on individual as well as family performance can be used to select the best individuals to retain in the orchards. Use of the index will result in retention of more families than under alternate schemes and permit more rigorous selection within families. A broad genetic base is maintained, the dangers of inbreeding are reduced, and the greatest genetic gain is assured. This scheme was applied to a set of data from a 90-seed-source test, a complement of seed sources was selected, and flowering and cone data from these seed sources were used to predict early seed yields in jack pine seedling seed orchards. After initial thinning, 1 hectare of orchard established according to the suggested scheme may yield 266.8 M full seed annually. This is probably a conservative estimate.

When grown under short rotation on good sandy soils, jack pine grows rapidly and produces a greater volume of pulpwood than red pine (Wilde et al. 1965). Although small amounts of jack pine are being planted in the Lake States, it is expected to play an increasing role in Lake States planting programs as the demand for paper and paper products increases (King 1973).

Jack pine grown under standard nursery and field conditions produces male and female strobili at 3 to 6 years of age. However, by forcing growth with long photoperiod, fertilization, and wide spacing in the greenhouse and nursery, flowering can be advanced to as early as 17 months after sowing seed (Rudolph 1966, Jeffers and Nienstaedt 1972). Thus, the time between sexual generations in jack pine can be reduced to less than 3 years (Rudolph 1966). With rapid generation turnover, repeated cycles of selection, progeny testing, and breeding can be used to genetically improve jack pine in a short time (King 1973).

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Establishing seedling seed orchards appear to be the best method for mass producing genetically improved jack pine because this species flowers at an early age and presents serious graft incompatibility problems.[2]

Methods for establishing jack pine seedling seed orchards have been suggested by King (1973), Yeatman (1974a) and Klein (1974). This paper includes a brief outline of their schemes. Results obtained from a nursery and field test of jack pine seed sources are used to describe an alternate scheme and to estimate projected early seed yield from the seed orchards.

JACK PINE SEEDLING SEED ORCHARD ESTABLISHMENT

King's Method

King's (1973) scheme begins with selecting--on the basis of seed source tests--the better seed collection areas for the planting region. Between 300 and 400 trees are chosen--no more than 15 individuals per stand--and open-pollinated seed collected and sown in a replicated nursery test. After 2 years' nursery growth, the 200 fastest growing families are selected and used to establish 2 or 3 test plantings on different sites in the planting area. The progeny test plantings are converted to seed orchards when the trees begin to bear regular pollen and cone crops--about 7 to 8 years after field planting. The plantings are measured at this time and thinned by removing all trees from below-average seedlots and some of the poorer trees from above-average seedlots. The plantings are remeasured at age 12 to 14 years and thinned to leave 1 out of every 4 trees of the best 25 seedlots.

Yeatman's Method

Yeatman (1974a) suggests improving the natural populations for seed collection by converting seed production areas into seedling seed orchards. When original stands are cut, replant them with local plus-tree progenies. Yeatman recommends systematically sampling 100 to 200 plus-trees on a unit area basis to avoid selecting close relatives. Selected trees are grafted and included in breeding archives. Open-pollinated progenies are used in first generation orchards followed by controlled-pollinated families (full-sib) from selected parents. Parents are selected for their breeding value determined initially from clonal tests (stem and branch form) and subsequently from progeny tests (survival and growth). Small half-sib family plots are initially established at 1.0 to 1.5 m spacings. A two-stage thinning operation is used: first thinning at 6 to 8 years to about half the original stocking, and second thinning at 11 to 14 years. Ultimately, 30 to 50 percent of the families are selected and family plots are thinned to a single tree per plot.

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[2] Unpublished data on file at the Institute of Forest Genetics, North Central Forest Experiment Station, Rhinelander, Wisconsin.

Klein's Method

Klein (1974) reports a design composed of 20 half-sib families, that have little or no co-ancestry from each of 11 geographic areas. The orchard consists of 24 blocks; each block contains 11 plots (area collections); each plot contains one tree from each of the 20 half-sib families from each area collection. Selection thinnings ultimately reduce the number of trees to one per plot. After thinning, each block contains 11 trees, each from a different area; thus, mating occurs predominantly among sources.

My Method

The scheme I suggest follows King's (1973) closely, deviating only in the selection processes used to rogue the orchards. All families are field tested and selections are based on a combination of seed source, family and individual tree performance. Some outstanding individuals within below average families may be selected but more families are included in the orchards and the dangers of inbreeding are reduced.

The scheme will be applied to a set of data from a 90-seed-source test, a complement of seed sources will be selected, and flowering and cone data from these seed sources used to predict early seed yields in jack pine seedling seed orchards.

THE EXAMPLE SEEDLING SEED ORCHARD

Seed Source and Parent Tree Selection

The 20 most promising seed sources were chosen in our northern Wisconsin planting of the rangewide seed source study initiated by the Canadian Forestry Service, Petawawa Forest Experiment Station at Chalk River, Ontario, in 1962 (Yeatman 1974b), (Table 1). Total heights of the trees from the 90 seed sources at age 11 was the sole selection criterion. The local source from Nokomis, Wisconsin, (2233) ranked 13 among the 20 selected sources. Trees from the Cloquet, Minnesota, source (2242)--the best of the 20 seed sources--were about 9 percent taller than those from Nokomis, while the poorest trees from the Constance Bay, Ontario, source (2208) were about 4 percent shorter than local trees.

For our purpose, the procedure used rather than the actual seed sources selected is the important point. In a seed source study of 90 to 100 sources tested at a single location in the planting area, we should select 10 to 25 of the most promising sources for retesting at additional test locations in the planting region. Inclusion of material from 10 or more sources will help to assure a broad genetic base for advanced generation breeding. And increased adaptive variability may result from crosses between individuals with different adaptive characteristics (Zobel 1971).

Table 1.--Projected seed yield from a young jack pine seedling seed orchard[1]

Source No. IFG	Source No. PFES	State or Province	Local Name	Lat. °N	Long. °W	Female strobili[2] tree	Female strobili[2] ha	Cones[3] ha	Seed[4] ha
2242	3279	MN	Cloquet	46.7	92.6	10.8	1,728	864	21,600
2230	3267	WI	Nekoosa	44.3	89.7	2.8	448	224	5,600
2236	3273	MI	Marl Lake	44.5	84.7	4.7	752	376	9,400
2231	3268	WI	Waupaca	44.3	89.0	8.6	1,376	688	17,200
2241	3278	MN	Brainerd	46.3	94.2	5.1	816	408	10,200
2211	3247	QUE	Harry Lake	46.4	76.2	5.9	944	472	11,800
2238	3275	MI	Gladstone	46.0	86.5	9.7	1,552	776	19,400
2246	3283	MAN	Hadashville	49.5	95.8	7.5	1,200	600	15,000
2209	3244	QUE	Fort Coulonge	45.8	76.7	9.1	1,456	728	18,200
2243	3280	MN	Cass Lake	47.3	94.6	5.8	928	464	11,600
2235	3272	MI	Fife Lake	44.6	85.4	4.9	784	392	9,800
2229	3266	WI	Wisconsin Dells	43.8	89.8	2.0	320	160	4,000
2233[5]	3270	WI	Nokomis	45.6	89.8	8.1	1,296	648	16,200
2210	3246	ONT	Petawawa Plains	45.8	77.4	10.3	1,648	824	20,600
2207	3242	ONT	Douglas	45.5	76.9	8.6	1,376	688	17,200
2232	3269	WI	Mosinee	44.8	89.7	9.0	1,440	720	18,000
2225	3262	ONT	Gowganda Lake	47.6	80.7	4.5	720	360	91,000
2192	3227	QUE	St. Louis de France	46.4	72.6	9.3	1,488	744	18,600
2228	3265	WI	Lone Rock	43.6	90.2	2.8	448	224	5,600
2208	3243	ONT	Constance Bay	45.5	76.1	3.9	624	312	7,800
			Mean or Total			6.7	21,344	10,672	266,800

1 Seed yields per hectare of orchard; 3,200 trees/ha
2 Data from a 5-year nursery test; 160 trees/source
3 50 percent female strobili to mature cones
4 Twenty-five full seed/cone
5 Local source

The example in Table 1 includes only 12 seed sources from the Lake States: more Lake States seed sources would have been desirable. The other eight seed sources are from Manitoba, Ontario, and Quebec. Of these, the Manitoba source probably is very similar to sources in northern Minnesota. Early results in our Wisconsin test suggest that the other seven seed sources are adapted to environmental conditions similar to our test site. The choice of such geographically widely separated seed sources for inclusion in a regional breeding program may be questionable. Advantages of such broad sampling have not been proven biologically and collection from widely separate origins may not be economically feasible. Until more research data is available, one may choose to restrict selection of seed sources to the planting region.

Phenotypic selection of 10 trees in each of the 20 selected stands will provide 200 half-sib families for establishing the progeny test seedling seed orchard. Selected trees should be at least 500 feet apart in a stand to minimize common ancestry. Consequently, it is best to select from relatively "large" stands on good sites, rather than from "small" stands on poor sites. The trees selected should be dominant and with good stem form, a wide branch angle, little evidence of serious second flushing characteristics (Rudolph 1964), and no insect or disease damage. It will not be worthwhile to spend much time and money on the selection of the parent trees using systems such as the "comparison tree method." Simple phenotypic selection of the individual parent trees after a quick survey of the stand is all that is required.

Establishment of Progeny Test-Seedling Seed Orchard

For the greatest return from a jack pine breeding program, genetically improved stock should be planted on the best jack pine sites. Therefore, the test plantings should be established on better sandy loam soils with a climate similar to the planting region (Wilde et al. 1965).

A randomized, complete block design with two to four tree family plots is recommended. Rows should be spaced wide enough (2.5 m) to permit use of equipment in the planting for the first few years after establishment. Trees within rows should be planted at close spacings (0.5 m) to permit early culling of the poorest trees. Thus, at an initial spacing of 0.5 by 2.5 m, 1 hectare of planting will contain 8,000 trees (20 sources, 10 families per source, and 40 seedlings per family).

Six to 8 years after establishment the trees in the progeny test should be evaluated for height and diameter growth, form, and pest incidence. A combined selection index based upon individual as well as family performance is then used to select the best individuals (Falconer 1960).

Thinning schemes similar to those recommended by King (1973), Yeatman (1974a), and Klein (1974) that result in elimination of a large proportion

of families based on average family performance ignore differences in variation patterns among individuals within the families. Combined selection assures the greatest genetic gain and because a large number of families are retained after roguing, a broader genetic base will be maintained in first generation orchards. This may result in greater potential genetic gain in advanced generation orchards (Canavera 1975).

A second generation of orchards can then be established using controlled pollinated full-sib families produced from the best individuals from the first generation orchard. Selected parents from two or more orchards in the planting area should be included in the crossing scheme and new selections should be added to the program periodically to keep the genetic base as broad as possible.

PROJECTED SEED YIELD

The number of female strobili per tree (table 1) at the beginning of the fifth growing season in a nursery test was used to estimate annual seed production from a young jack pine seedling seed orchard established according to the scheme recommended in this paper.

If an average of 160 individuals from each of the 20 seed sources are retained in the seed orchard after the initial thinning, then 1 hectare of orchard may produce 266.8 M full seed annually, an equivalent of 213.4 M plantable seedlings. The basic assumptions used in this example are: (1) the trees in the orchard will produce the same number of females as in the nursery test, (2) 50 percent of the female strobili will mature into cones, (3) there will be 25 full seed per cone, and (4) 80 percent of the full seed will yield plantable seedlings.

The 50 percent female abortion rate is based on actual observation over a number of years. Twenty-five full seed per cone is an average based on a preliminary study of the seed yield from individual cones (Jeffers 1972). Newer studies now in progress suggest that 25 seeds per cone may be a conservative estimate. We set the percent plantable seedlings at 80 percent of full seed because the USDA Forest Service (1974) reports germination capacities from 69 to 87 percent and because seed from seed orchards should be of high quality in a physiological sense as a result of insect control and optimum growing conditions. However, the goal should be germination capacities exceeding 90 percent because plant production should be under optimum conditions in the nursery or greenhouse and culling should not exceed 10 percent.

Thinning is likely to remove some of the provenances and perhaps some families within the remaining provenances from the production seed orchard. Depending on the provenance and family variation in strobili production, this could affect the potential for seed yield after roguing.

The seed sources are arranged in order of decreasing heights in table 1 (352 cm to 310 cm); it is clear that the correlation between heights and seed potential is not significant (r = 0.170). Therefore, the effect of roguing on the basis of heights would be random in terms of seed yield. Family variation within provenances in potential seed production is significant (Jeffers and Nienstaedt 1972), but there is nothing that would suggest that the roguing would reduce the seed production potential.

The projected seed yields are probably conservative. Because seed for the rangewide seed source test was sown directly in the nursery and the trees were grown at a 1 by 1 foot spacing, the number of females produced per tree probably is less than the number produced by orchard trees grown at wider spacings. By sowing progeny test seeds in the greenhouse and raising the seedlings under intensive greenhouse, nursery, and field techniques, earlier and heavier flowering will occur (Rudolph 1966), and thinning of seed orchards will promote crown development resulting in additional increased flower production among remaining trees.

The projected seed yield data indicate that a five-fold difference in seed yields may exist among trees from different seed sources. And variation in number of females per tree among trees within sources in our nursery test were even greater. This great variation in seed yield among different genotypes will continue to exist throughout the life of a seed orchard, but we have no assurance that the early good seed producers will continue to be the best. And we don't know if the best seed producers will have continued fast vegetative growth. Studies on other species suggest that this will not be the case. This lack of information necessitate continued research on flowering and potential seed yield. In addition, much valuable information may be obtained if seed orchard managers in the future will keep accurate records of growth, flowering, and seed production throughout the life of the orchards.

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CONTROLLED POLLINATION IN EASTERN REDCEDAR AND ROCKY MOUNTAIN JUNIPER[1]

Gilbert H. Fechner[2]

ABSTRACT.--Pollination with forced and fresh eastern redcedar pollen was compared to wind pollination (and unpollinated controls). This is the first attempt at controlled pollination in juniper. Seeds were extracted, and cutting tests and germination tests were conducted to evaluate the success of pollinations. Artificial crosses were also made with eastern redcedar pollen on a single Rocky Mountain juniper female tree. First-year fruits were collected and evaluated. Preliminary results indicate that wind pollination is less reliable than control-pollination in obtaining sound seed set of eastern redcedar. This may explain the high proportion of empty seeds found and the low reproduction obtained in many natural stands.

INTRODUCTION

The low proportion of filled seeds in developed fruits of *Juniperus* L. has been observed frequently. This low set of sound seeds may be the result of poor pollination due to a lack of synchronization between pollen release from male trees and ovular receptivity on female trees in the vicinity. If this were true, artificial pollinations could enhance sound seed set, provided that pollen viability could be maintained. However, the only previous report of artificial pollination in juniper is that of Djavanshir (1974) in which pollen was applied to non-isolated female strobili of *Juniperus polycarpos* C. Koch in Iran.

Rocky Mountain juniper (*J. scopulorum* Sarg.) has long been considered a western form of eastern redcedar (*J. virginiana* L.). In fact, early western explorers and botanists (James 1823; Torrey 1828) did not recognize the subtle differences that were later used to separate these two species. Recently field studies of several North American junipers have revealed individuals possessing combinations of morphological characteristics belonging to different species. Intergrades have been noted between eastern redcedar and Ashe juniper (*J. ashei* Buchholz) (Hall 1952a, 1952b, 1955), between eastern redcedar and Rocky Mountain

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juniper (Fassett 1944; Van Haverbeke 1968), and between Rocky Mountain juniper and creeping juniper (J. horizontalis Moench) (Van Haverbeke 1968). These intergrades have been presumed to be the result of inter-species hybridization. However, no controlled crossing attempts intended to verify such presumptions have been reported.

The objectives of this study were, therefore, (1) to compare the fruit and seed set, seed germination, and initial seedling development resulting from controlled pollination with stored or fresh eastern red-cedar pollen; and (2) to attempt artificial crosses between Rocky Mountain juniper and eastern redcedar.

METHODS

Beginning in October 1973 and continuing through February 1974, branches were collected at 10-day intervals from two eastern redcedar male trees (Tree A and Tree B) on the Colorado State University campus. The branches were forced in water at room temperature (25 to 27°C), and the pollen obtained was stored in cotton-stoppered vials at 0 to 4°C. Fresh pollen was extracted from the male trees on March 4, 1974.[3]

On February 27, 1974, before receptivity, strobili were isolated on three eastern redcedar female trees (JV-1, JV-2, JV-3) on the Colorado State University campus. First pollinations with fresh and stored pollen were made March 7 and 8 on trees JV-1 and JV-3 and on March 11 on JV-2. Receptive female strobili, terminal on short lateral shoots, were reddish-yellow to brownish in color. Repollinations were performed on March 11, 15, and 21. All bags received three pollinations; some received four, depending on the amount of pollen available. Unpollinated and wind-pollinated control bags were maintained on all three female trees. Pollen treatments were assigned randomly to the bags.

Branches on a single Rocky Mountain juniper female tree were isolated on March 5, 1974, and pollinations with a single eastern redcedar male (Tree A) were made on April 25, when Rocky Mountain juniper male trees were actively shedding pollen, and again on May 2. Unpollinated and wind-pollinated controls were maintained.

Isolation bags were removed from the tagged branches of the eastern redcedar females on April 25 and from the Rocky Mountain juniper female on May 16, when wind-pollinated branches were also marked. On October 23 and 25, 1974, the eastern redcedar branches were collected and placed into labeled bags; the same was done for the Rocky Mountain juniper bags on December 20, 1974.

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3 Natural pollen shed began on the two male trees on March 6 and continued until March 15. Peak pollen shed was March 11.

Between October 1974 and January 1975, all of the developed fruits were measured to the nearest 0.1 mm, and the seeds of 90 percent of the fruits were cut to determine whether they were filled or empty. Seeds from 10 percent of the fruits from each female x male combination were washed, their tips cut (Djavanshir and Fechner 1975b)[4], and the seed stratified between moist paper toweling in petri dishes at 5°C.

On May 6, 1975, the stratified seeds were divided into two replicates from each of the pollination bags and transferred to an incubator for germination tests under an 18°C, 14-hour day/8°C, 10-hour night regime. Germination of seeds was recorded at approximately 3-day intervals until June 12, 1975. Seedling length was also measured, and when the cotyledons had shed their seed coats, the seedlings were transplanted into plastic pots containing vermiculite; they were watered and kept at the same temperature-light regime as the seeds. Beginning on June 17, Hoagland's nutrient solution was used for watering at 3-day intervals until the study was terminated July 8, when the seedlings were measured and their dry weights obtained.

RESULTS AND DISCUSSION

Fruit Set

No fruit was set on branches of either eastern redcedar or Rocky Mountain juniper in the absence of pollination,[5] but undeveloped female strobili were still identifiable on unpollinated control branches when the branches were collected.

Average fruit set per unit dry weight of bagged branchlet varied among the pollen sources and among the three eastern redcedar female trees. Higher fruit set was obtained on each female tree with fresh pollen than with stored pollen from the same male tree. Fresh pollen from Tree B produced a higher fruit set than fresh pollen from Tree A or wind-borne pollen. Pollen from Tree A produced a lower fruit set than wind-borne pollen on two of the trees (table 1). Variation in fruit set among the female trees may simply reflect difference in the number of strobili produced in the study year.

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4 Djavanshir, K. and Gilbert H. Fechner. 1975b. Epicotyl and hypocotyl germination of eastern redcedar and Rocky Mountain juniper. Unpublished manuscript.

5 An exception was a single fruit containing a single empty seed that may have resulted from unknown contamination (see table 1).

Table 1.--Fruit set from controlled polliation on eastern redcedar and Rocky Mountain juniper

INTRASPECIFIC CROSSES

Female parent 1/	Date, type pollination by male parent 2/	Bags	Fruit set: Total	Fruit set: Per gram branch weight
		Number	Number	Number
JV-1	A Feb. 10	1	2	0.26
	A Fresh	2	162	5.83
	B Dec. 31	3	48	2.50
	B Feb. 10	3	94	1.82
	B Fresh	2	300	6.22
	Wind	5	117	1.70
	Unpollinated	3	1	0.04
JV-2	A Jan. 31	1	11	1.01
	A Fresh	3	55	1.52
	Wind	5	152	1.66
	Unpollinated	2	0	0.00
JV-3	A Jan. 31	2	26	0.56
	A Fresh	4	140	1.22
	B Jan. 10	3	149	1.71
	B Fresh	3	192	2.60
	Wind	5	201	1.48
	Unpollinated	2	0	0.00

INTERSPECIFIC CROSSES

Female parent 1/	Date, type pollination by male parent 2/	Bags	Fruit set: Total	Fruit set: Per gram branch weight
JS-1	A Fresh	17	122	0.36
	Wind	5	218	2.48
	Unpollinated	4	0	0.00

1/ JV = *J. virginiana*; JS = *J. scopulorum*.

2/ "A" and "B" are *J. virginiana* male trees

Fruit set was obtained in 13 of 17 bags on Rocky Mountain juniper cross-pollinated with eastern redcedar, but fruit set per unit branch weight was only about 1/7 that obtained by wind pollination. Fruit set per cross-pollinated bag was extremely variable, averaging 7.6 fruits per bag $\pm$ 5.46 (2S.E.); in contrast, wind pollination resulted in an average set of 43.6 fruits per bag. The most likely source of wind-borne pollen is several Rocky Mountain juniper male trees near the JS-1 female.

The fruits of both study species are irregularly ellipsoidal in shape, usually elongated along the cone axis. Fruit length varied from 4.0 to 8.1 mm (average 5.8 mm) for the four trees, and fruit width varied from 2.8 to 6.5 mm (average 4.5 mm). The Rocky Mountain juniper fruits were significantly larger than those of the grouped eastern redcedar trees, primarily due to exceptionally small fruits on one of the latter, according to Duncan's multiple range test (95 percent level of probability).

Seed Set

The set of sound seed on eastern redcedar varied among the female trees studied, JV-1 averaging 0.90 sound seeds per fruit, significantly higher than the other two trees (table 2). Seed set differed significantly among the pollen sources within the JV-2 and JV-3 female trees, primarily due to one pollen treatment, Tree A Jan. 31, which was high on one tree and low on the other tree. Of particular interest, however, is the fact that stored pollen was usually as effective, or more so, in bringing about sound seed set as fresh pollen from the same male parent or wind-borne pollen were. This supports the suggestion that tube length of eastern redcedar pollen _in vitro_ after storing is a measure of its ability to affect _in vivo_ fertilization (Djavanshir and Fechner 1975a). The considerable bag-to-bag variation observed suggests that other factors were more important in affecting sound seed set than simply the pollen sources used. No doubt the precise timing of receptivity of the female strobili varied from bag-to-bag, and even though several pollen applications were made, ideal pollination conditions may not always have existed.

Seed set did not differ significantly between the cross-pollinated and the wind-pollinated branches of the Rocky Mountain juniper female, averaging 0.90 sound seeds per fruit. Eastern redcedar pollen was as effective in producing sound seed in fruits that were set as was wind-borne pollen. Thus, incompatibility barriers between these two species are not absolute.

The set of empty seeds was high. In 28 percent of the fruits set on both species studied, only empty seeds were found. In an additional 14 percent, one or two empty seeds were found with at least one filled seed. The presence of pollen is apparently essential to the development of fruit; furthermore, the presence of pollen in the fruit or in the ovule also assures seed development.[6] It therefore seems clear that empty seeds in

6 In a single fruit on one eastern redcedar tree, no seeds were found.

Table 2.--Seed set from controlled pollinations in eastern redcedar and Rocky Mountain juniper

INTRASPECIFIC CROSSES

Female parent[1/]	Date, type pollination by male parent[2/]	Fruits	Empty seeds	Filled seed set: Total	Filled seed set: Average per fruit
		---------- Number	----------	----------	----------
JV-1	A Feb. 10	2	0	2	1.00
	A Fresh	145	71	119	0.84
	B Dec. 31	43	19	49	1.14[3/]
	B Feb. 10	84	40	66	0.79
	B Fresh	267	118	279	1.04
	Wind	105	50	73	0.70
	Unpollinated	1	1	0	0.00
	Mean				0.90
JV-2	A Jan. 31	9	8	2	0.22
	A Fresh	49	35	33	0.67
	Wind	137	91	73	0.53
	Mean				0.55
JV-3	A Jan. 31	23	5	25	1.09
	A Fresh	128	80	91	0.71
	B Jan. 10	135	88	99	0.73
	B Fresh	172	96	141	0.82
	Wind	179	90	111	0.62
	Mean				0.74

INTERSPECIFIC CROSSES

Female parent	Date, type pollination by male parent	Fruits	Empty seeds	Total	Average per fruit
JS-1	A Fresh	112	50	98	0.88
	Wind	196	78	180	0.92
	Mean				0.90

1/ JV = *J. virginiana*; JS = *J. scopulorum*.

2/ "A" and "B" are *J. virginiana* male trees.

3/ Differed significantly from wind pollination of same female tree.

the study species cannot be attributed to the lack of synchronization between pollen release and ovular receptivity. However, the high proportion of empty seeds suggests either that fertilization is not essential to seed development, or that some post-fertilization incompatibility reaction brings about a tissue breakdown within the ovule. There was no noticeable difference in the size of filled or empty seeds, so the presence of pollen must trigger some mechanism which allows ovular development to proceed. As long as 50 years ago, the Russian physiologist Doroshenko (1928) claimed that the function of pollen in ovules is physical and that development could take place without fertilization. Our results in juniper do not discount Doroshenko's claim.

The number of seeds per fruit varied from 1 to 3 in both eastern redcedar and Rocky Mountain juniper. A single seed developed in 69.0 percent of the eastern redcedar fruits and in 66.1 percent of the Rocky Mountain juniper fruits. Three seeds per fruit occurred in very low frequency, 1.9 and 1.3 percent, respectively, for the two species. There was no significant difference in the number of seeds per fruit among the female trees nor among the pollen sources.

According to Mathews (1939), three types of female strobili are found in eastern redcedar:

1. Only one ovule, borne in the axil of one member of a sporophyll pair (2/3 of the fruits are of this type).

2. Two ovules, side by side in the axil of one member of a sporophyll pair; the other sporophyll is sterile (1/6 are of this type).

3. Two ovules, each separately on a fertile member of a sporophyll pair (1/6 of this type).

Mathews further found that if three seeds develop, a combination of the latter two types is usually the explantation. More than four seeds are produced rarely, and only when a second pair of sporophylls participates. Thus, one and two seeds per fruit are expected to be in the approximate proportions that our data show.

Seed Germination

The real germination percent (germination percent of filled seeds) was generally high among all eastern redcedar female x male parental combinatio producing adequate numbers of seeds to test (table 3). On all three female trees, however, real germination of wind-pollinated seed was somewhat lower than control-pollinated seed from the same mother trees. Possibly, the presence of foreign pollen (e.g., that of another juniper species) could bring about seed filling without a viable embryo.

Table 3.--Germination of eastern redcedar and Rocky Mountain juniper seeds from controlled and wind pollinations[1/,2/]

INTRASPECIFIC CROSSES

Female parent[3/]	Date, type pollination by male parent[4/]	Total	Seeds germinated	Real germination[5/]	Plantable seedlings	
		Number	Number	Percent	Number	Percent
JV-1	A Fresh	21	16	94.2	12	75.0
	B Dec. 31	8	7	100.0	5	71.4
	B Feb. 10	13	9	90.0	1	11.1
	B Fresh	37	32	88.9	17	53.1
	Wind	12	6	60.0	0	0.0
JV-2	A Fresh	2	2	100.0	0	0.0
	Wind	6	2	40.0	1	50.0
JV-3	A Jan. 31	4	4	100.0	2	50.0
	A Fresh	10	10	100.0	9	90.0
	B Jan. 10	10	10	100.0	9	90.0
	B Fresh	12	12	100.0	10	83.3
	Wind	10	9	90.0	6	66.7
INTERSPECIFIC CROSSES						
JS-1	A Fresh	15	0	0.0	0	0.0
	Wind	25	0	0.0	0	0.0

1/ From two petri-dish replications for each parental combination.

2/ Following 150 days stratification at 5°C (98 days for Rocky Mountain juniper); seed tips cut.

3/ JV = *J. virginiana*; JS = *J. scopulorum*.

4/ "A" and "B" are *J. virginiana* male trees

5/ Real germination = germination percent of filled seeds.

Although real germination was surprisingly uniform, the number of plantable seedlings obtained varied among the eastern redcedar mother trees and among the pollen parents. Whereas, the JV-1 female was superior to the JV-3 in fruit set per unit branch weight and in the set of sound seeds per fruit, the reverse was true for the percentage of plantable seedlings developing from germinated seeds. The percentage of plantable seedlings was usually higher for fresh pollen than for stored pollen, but this difference was not statistically significant. The factors influencing early seedling vigor are not clear.

No germination of the one-year seeds from the Rocky Mountain juniper female was obtained from either the wind- or cross-pollinated treatments. Following the completion of the germination tests, the central portion of the filled seeds, considered to be an embryo cavity, was removed, killed in FAA, and prepared for microscopic examination to determine the stage of development. A total of 27 microscope slides were thus prepared. The material examined was entirely cellular female gametophyte tissue, with no evidence of the presence of archegonia. Seeds from both the cross- and wind-pollinations contained this material; no difference could be detected.

Interpretation of the one-year seed development in Rocky Mountain juniper is difficult. Unfortunately, the reproductive cycle of this species has not been worked out. However, the sequence of its developmental stages is evidently different from that observed in other juniper species and other gymnosperm genera. For example, in the one-year-maturing eastern redcedar, the female gametophyte develops during the spring, a few weeks after pollination, the archegonia differentiating and fertilization occurring by late June or July (Ottley 1909; Mathews 1939). This is not a great deal different from other one-year-maturing gymnosperms such as spruce (Picea A. Dietr.), whose female gametophyte is at the free-nuclear stage at the time of pollination (Fechner 1964).

In the three-year-maturing common juniper (J. communis L.), the female gametophyte develops during the second season, the megaspore mother cell not differentiating until April of the year following pollination (Ottley 1909). And in the two-year-maturing pine (Pinus L.), the megaspore mother cell is differentiated at the time of pollination, and the ovules overwinter in the early free-nuclear gametophyte (Ferguson 1904; McWilliam 1958).

None of the above examples describes the two-year-maturing Rocky Mountain juniper seeds observed in this study. We found that the cellular female gametophyte stage was reached by late autumn of the first year, although it had only replaced about one-fourth of the nucellus tissue. It is not known if interspecies crosses occurred, since no developimg embryos were found. However, the similar first-year development of the cross-pollinated and wind-pollinated seeds strongly suggests that hybridization is possible between Rocky Mountain juniper and eastern redcedar.

Seedling Development

Seedling survival to 27 to 46 days following transplanting was variable among both eastern redcedar female trees (JV-1, JV-3). Nor could a pattern be recognized relative to seedling vigor; some of the seedlings resulting from stored pollen were as vigorous as those from fresh pollen.

Pollen source did not significantly affect the dry weight of the surviving seedlings. Average seedling weight at the end of the study was 0.0034 grams, ranging from 0.0018 to 0.0055 grams. The ratio of top length divided by root length was variable within and between female x male parental combinations (table 4), ranging from 4.20 for the smallest tree (0.0018 grams dry weight, 52 mm total length) to 0.60 for the largest tree (0.0055 grams dry weight, 134 mm total length). The average ratio was 1.00, and the average length was 94 mm.

Table 4.--Development of eastern redcedar seedlings from controlled and wind-pollinations

Female parent1/	Date, type pollination by male parent2/	Surviving seedlings July 83/		
		Number	Percent4/	Average top-root ratio
JV-1	A Fresh	4	33.3	1.41
	B Dec. 31	3	60.0	.79
	B. Feb. 10	1	100.0	.69
	B Fresh	9	52.9	1.10
JV-3	A Jan. 31	2	100.0	2.13
	A Fresh	5	55.6	1.51
	B Jan. 10	8	88.9	.95
	B Fresh	8	80.0	.80
	Wind	3	50.0	1.93

1/ JV=*J. virginiana*. 2/ "A" and "B" are *J. virginiana* male trees. 3/ Seedlings apparently living but without root systems not included. 4/ Percent of seedlings transplanted, May 23-June 12.

CONCLUSIONS

This study shows that the presence of pollen is necessary for the development of fruit in both eastern redcedar and Rocky Mountain juniper, and the presence of pollen in the fruit or in the ovule assures seed development. The occurrence of empty seeds cannot be attributed to lack of synchronization between pollen release and ovular receptivity. Furthermore, pollen of eastern redcedar extracted as much as 2 months prior to normal pollen shedding and then stored is effective in producing sound seed set and vigorous seedlings to at least 40 days.

The results of this study also suggest that on the basis of fruit set, sound seed set, and first-year female gametophyte development,

hybridization is possible between eastern redcedar and Rocky Mountain juniper. Further study is necessary to determine the degree of compatibility between them.

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GEOGRAPHIC VARIATION OF GROWTH AND WOOD PROPERTIES IN JAPANESE LARCH IN SOUTHWESTERN LOWER MICHIGAN[1]

Chen Hui Lee[2]

ABSTRACT--Growth and wood characteristics at age 10 from planting were assessed on the 22 seedlots of Japanese larch outplanted in the Kellogg Forest, Augusta, Michigan using a randomized complete block design. Results did not indicate any geographic trends for most traits studied but did suggest the operation of genetic drift and inbreeding. Fast growing seedlots continued to perform well in southwestern Lower Michigan. Recommends that seed for plantings in the Lake States area should be from the Mt. Nantai area in the northeast species range.

Japanese larch (*Larix leptolepis* (Sieb. et Zucc.) Gordon) is one of the most important economic species of Japan. It is found in the subalpine regions of Central Japan and attains sizes up to 30 meters in height and 1 meter in diameter (Japan For. Tech. Assoc. 1964). The wood is heavy, decay resistant, holds nails well, and pulps readily using the sulfate process. The species is extensively used for reforestation outside its natural range in northern Japan, Europe, the United States, and Canada because it grows fast and is valued for ornamental uses. It can be propagated readily from cuttings collected from young trees (Chandler 1967).

The natural range of Japanese larch is small (about 200 kilometers square, from 900 to 2,500 meters in elevation) and is composed of several genetically isolated small populations, the largest being several kilometers across and the smallest a hectare or so in size (Wright 1962). Considerable improvement of this species can be expected through a careful selection and breeding program because previous studies indicated that there were significant differences in growth performance. These include

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studies conducted in Minnesota (Pauley et al. 1965), Wisconsin (Lester 1964), Midwest (Farnsworth et al. 1972), New York (Stairs 1966), Maryland (Genys 1972), and Germany (Langner 1958 and 1961; Hattemer 1968 and 1969; Langner and Stern 1965).

The study reported here consisted of 22 seed sources of Japanese larch grown at the Kellogg Experiment Forest, Augusta, Michigan. The objectives were to continue to assess the growth performance, to collect new genetic information on the geographic variation pattern of wood properties, and to analyze the growth-wood properties relationships.

MATERIAL AND METHODS

The study was initiated by Dr. W. Langner of Germany. Seed was collected from 25 natural stands throughout the species range by the Japanese Government Forest Experiment Station, Meguro, Tokyo, Japan, in 1956. Each seedlot consisted of seed from several trees per stand. The seed was sent to branch stations of the Government Forest Experiment Station in Japan; Institut fuer Forstgenetik und Forstpflanzenzuechtung, Schmalenbeck, Germany; State University of New York College of Forestry at Syracuse; and Michigan State University, East Lansing, Michigan.

Michigan State University seeded 22 seedlots (table 1, fig. 1) in the research nursery at East Lansing on May 14, 1959. A randomized complete block design was used; extra seed was broadcast in a separate block to provide planting material for field tests.

In 1961, 2-0 seedlings were lifted and used for the establishment of the Kellogg study. A randomized complete block design with 22 4-tree plots in each of the 10 replications, and 2.4 by 2.4 meter spacing was used. Dead trees were replaced with 3-0 stock at the end of the first growing season. Amitrol-T was used for weed control.

The Kellogg plantation (MSFG 1-61) was one of the 17 test plantations established throughout the north-central States. The ground was relatively level with sandy loam soils. Survival at Kellogg was among the best when assessed in 1962 and 1967 (88 and 74 percent, respectively).

I measured total height to the nearest 7.6 centimeters (1/4 foot) and diameter at 0.3 meter (1 foot) from the ground to the nearest 1/4 centimeter(0.1 inch) on the two tallest trees per plot on August 5-6, 1971. Seedlot means were used as items in statistical analysis for the two growth traits studied.

I also extracted a 0.5 cm increment core at 1 foot above ground from the north side of the largest tree on each plot. After the debarking, the 1969 growth increment was removed from the core sample and split radially into two halves, one for the study of specific gravity and the other for tracheid length.

Table 1.--Origin data for the *Larix leptolepis* provenances

Schmalenbeck No. (MSFG No.)	North latitude	East longitude	Elev.	Mean annual temp.	Mean annual precipitation
	(degrees)	(degrees)	(m)	(^{o}C)	(mm)
Mt. Fuji					
1 (111)	35.4	138.7	1,320	6.2	1,820
2 (112)	35.4	138.7	1,760	5.0	1,760
Mt. Azusa					
4 (114)	36.0	138.7	1,500	6.5	1,360
Yatsuga Mountains					
5 (115)	36.0	138.4	1,780	6.1	1,550
6 (116)	36.0	138.4	1,750	5.4	1,480
7 (117)	36.1	138.3	1,600	5.1	1,430
8 (118)	36.0	138.3	1,700	5.4	1,700
9 (119)	35.9	138.3	1,450	6.8	1,560
10 (120)	35.9	138.3	1,750	6.1	1,330
Akaishi Mountains					
11 (121)	35.8	138.2	1,500	6.5	1,720
12 (122)	35.4	138.1	2,000	4.0	2,840
Mt. Nantai					
13 (123)	36.8	139.4	1,360	5.5	2,250
14 (124)	36.8	139.4	1,490	6.8	2,470
15 (125)	36.8	139.5	1,700	5.3	2,590
Mt. Shirane					
16 (126)	36.6	138.5	1,750	4.3	1,800
Mt. Asama					
17 (127)	36.4	138.5	1,900	3.2	1,890
18 (128)	36.4	138.6	1,420	6.2	1,400
19 (129)	36.4	138.5	1,700	4.3	1,570
Mt. Komaga					
23 (133)	35.8	137.9	1,820	3.2	2,380
Hida Mountains					
22 (132)	36.4	137.7	1,380	5.6	1,670
24 (134)	35.9	137.6	1,380	6.9	2,130
25 (135)	36.1	137.7	1,920	3.3	2,300

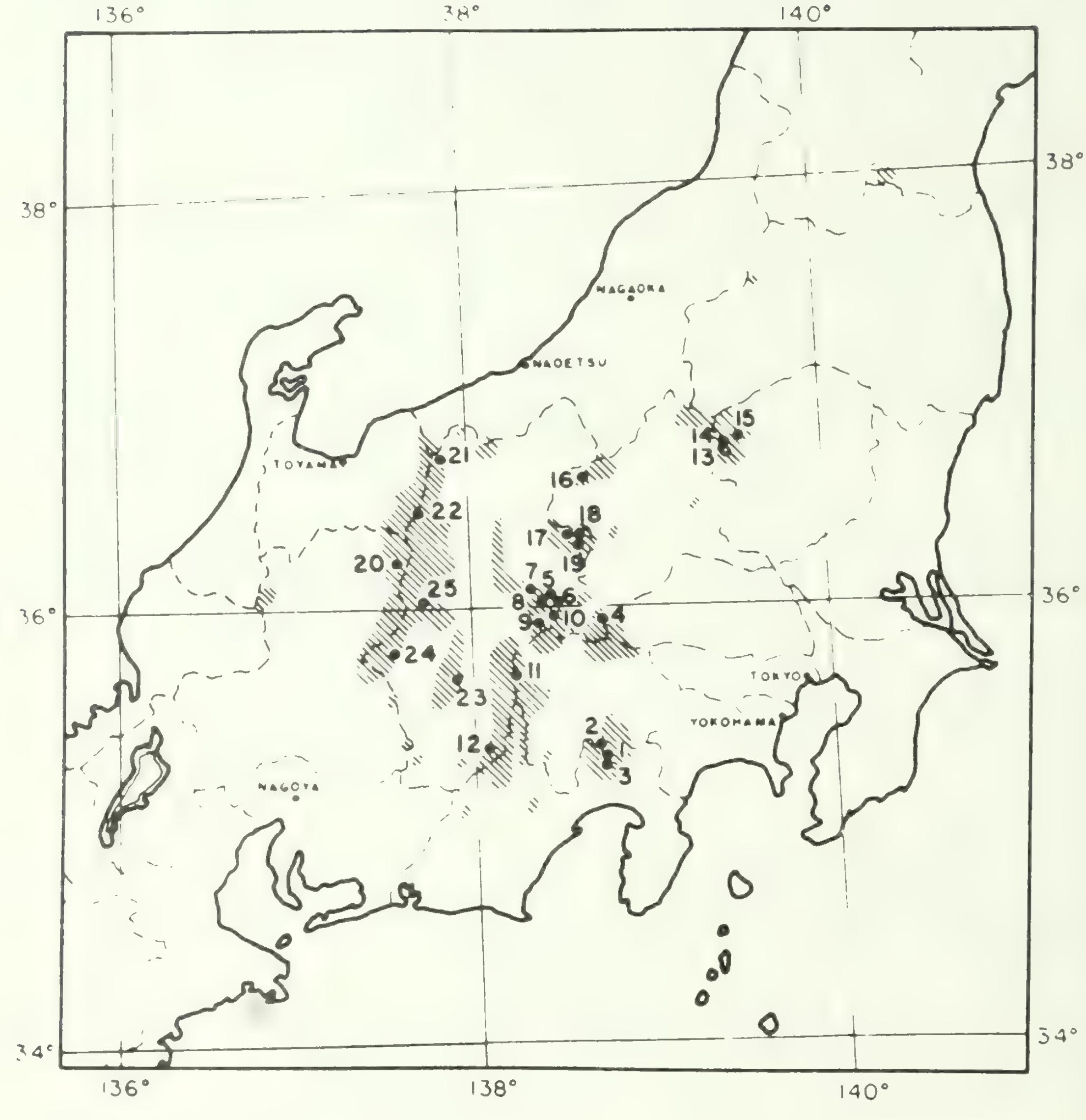

Figure 1.--Natural range (shaded) and location (numbered dots) of seedlots of Larix leptolepis after Farnsworth et al. (1972).

Alcohol-benzene extractives were removed because their presence tends to overestimate specific gravity (Taras and Saucier 1967). The specific gravity was determined following Smith's recommendation (1954).

Wood fibers were macerated in an equal mixture of glacial acetic acid and 30 percent hydrogen peroxide at 50-55°C for 72 hours. After several changes with distilled water, the macerated fibers (tracheids) were stained with 1 percent Bismarck Brown Y aqueous solution overnight and then mounted on slides. No dehydration or cover glass was used (Echols 1969), but fibers were measured directly to the nearest millimeter with 90 X magnification under the Bausch and Lomb No. 2700 projector.[3] They were then converted back to the actual tracheid length. Mean lengths of 20 tracheids were used as items in statistical analysis.

In the analysis of variance of growth and wood data, the degrees of freedom were 21, 9, and 189 for provenances, replication and error, respectively. However, there were 16 missing plots; the error term degrees of freedom were reduced accordingly. Rank correlation (d.f. = 20) was used to study the relations among growth, wood, and origin data of parent stands.

VARIATION IN GROWTH TRAITS

Height Growth

The between-seedlot differences in total height were significant at the 1 percent level (table 2). At age 10 after planting, seedlot 15 from Mt. Nantai continued to outgrow others.

Significant differences in juvenile height growth among 25 provenances were also reported by Langner (1961) at Schmalenbeck, North Germany, and by Hattemer (1968, 1969) at 13 localities throughout Germany; by Farnsworth et al. (1972) on the 18 test sites in north-central United States using 7 and 22 of the seedlots; By Lester (1964) who observed 6 seedlots in Wisconsin; by Stairs (1966) in New York (20 seed sources); and by Genys (1972) in Maryland (16 seedlots). All these studies were part of the international Japanese larch provenance testing program.

Despite it's narrow species range, variation in height growth was large. At age 10 from planting, seedlot means varied from 540 to 714 cm, a difference of 32 percent. This is roughly equivalent to 300 kg/m^3 or 20 lbs/ft^3 (62.4 lbs. x (1.32 - 1.00)) more wood production. The corresponding values obtained for eastern white pine (*Pinus strobus* L.)

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3 Mention of trade names does not constitute endorsement of the product by the USDA Forest Service.

Table 2.--Growth and wood properties of 22 Larix leptolepis provenances at age 12 from seed in southwestern Lower Michigan

Origin No., Mountain of origin	Height	Diameter at stump height	Height/ diameter ratio	Specific gravity	Tracheid length	Index wood production 1/
	(cm)	(cm)	(cm/cm)	(number)	(mm)	(number)
1 Fuji	663	11.7	57	0.400	2.08	1.05
2 Fuji	674	12.0	56	.424	2.11	1.19
4 Azusa	696	12.9	54	.392	2.17	1.31
5 Yatsuga	714	12.2	59	.388	2.12	1.18
6 Yatsuga	670	12.3	54	.374	2.06	1.09
7 Yatsuga	693	12.5	55	.405	2.07	1.27
8 Yatsuga	600	10.4	58	.404	2.08	.76
9 Yatsuga	673	12.1	56	.378	2.09	1.08
10 Yatsuga	683	12.6	54	.399	2.07	1.25
11 Akaishi	594	10.0	59	.412	2.13	.71
12 Akaishi	615	10.9	56	.393	2.13	.83
13 Nantai	636	11.4	56	.398	2.06	.95
14 Nantai	686	12.9	53	.386	2.03	1.27
15 Nantai	714	12.6	57	.405	2.13	1.32
16 Shirane	609	10.8	56	.403	1.99	.83
17 Asama	673	12.3	55	.390	2.00	1.14
18 Asama	655	11.1	59	.405	2.08	.95
19 Asama	540	9.5	57	.413	1.98	.58
23 Komaga	600	10.4	58	.441	2.05	.83
22 Hida	649	11.2	58	.411	2.06	.96
24 Hida	626	11.9	53	.379	2.03	.97
25 Hida	600	11.5	52	.366	2.04	.84
Mean	647	11.6	56	0.398	2.07	1.02
F	3.26**	2.49**	1.58*	1.79*	1.27	--

1/ Index $= \frac{\text{Height}}{\text{Mean Height}} \times \frac{(\text{Diameter})^2}{(\text{Mean Diameter})^2} \times \frac{\text{Specific Gravity}}{\text{Mean Specific Gravity}}$

and European black pine (Pinus nigra Arnold) from the same Kellogg Experiment Forest were 23 and 34 percent, respectively (Lee 1974, Lee and Wright 1975). These three species are test planted in the same general area with a high degree of precision as reflected in the small-sized (2.45 to 3.88 percent) coefficients of variability (the standard deviation to mean ratio).

The correlations between growth rate and the latitude, altitude, and mean annual precipitation at localities of parent stand were not significan

Similar results have also been reported by Pauley et al. 1965; Lester 1964; Farnsworth et al. 1972; Langner 1961; Schönbach et al. 1966, and Genys 1972). Fast growing seedlots were from the northern as well as the southern species range and, likewise, from low as well as high altitudes. However, I observed a distinct geographic trend between the 1971 height growth, longitude, and the mean annual temperature at seed origin. The rank correlation coefficients were 0.497 and 0.514; both significant at the 5 percent level. Schönbach et al. (1966) also observed a clearcut correlation between early frost resistance and the time of growth cessation. This suggests that clinal variation patterns in height growth essentially are temperature related; trees from the species' eastern range and from localities where mean annual temperatures are high grew faster and suffered less from the early autumnal frost.

Professor Jonathan W. Wright of Michigan State University generously furnished the 1974 height data (13 years after planting). Therefore, it was possible to compute the following age-age correlations.

Age in years \ Age in years	2	5	6	10	13
2	1.00	0.69	0.63	0.46	0.51
5		1.00	0.97	0.75	0.83
6			1.00	0.82	0.88
10				1.00	0.91
13					1.00

The rank correlation coefficients were all statistically significant at the 1 percent level; however, they tended to decrease as the plantation grew older. In general, fast growing seedlots at two years of age were still growing well at age 13, but some changes in the growth pattern have occurred. For example, seedlot 15 from Mt. Nantai ranked fifth in 1963 at age 2. It was the top performer in 1964, when it was 60 percent taller than the slowest growing seedlot. In 1966 (age 5) it was 70 percent taller than the shortest seedlot. This figure dropped to 37 in 1967 and to 32 percent in 1971; by 1974 - 13 years from seed - seedlot 15 ranked sixth. The story is somewhat similar to that of the southern Appalachian seedlots in eastern white pine (Lee 1974). Therefore, continued observation on the growth pattern is necessary because changes in relative height may continue to occur in the future.

It is important to determine the genotype x environment interactions for each provenance. My study was based on a single plantation and provided no information. However, according to Wright (1962), the Germany-Michigan correlation in height data was low. Provenances that were fast-growing in Germany were not necessarily good in Michigan. Langner and

Stern (1965) attributed the absence of a growth relation to severe winters in Michigan. In the recent study by Farnsworth et al. (1972), there were 7 common seedlots represented in 18 plantations throughout the north-central United States. They reported a strong genotype x environment interaction in height performance. Seedlot 15 was tallest at most test sites but grew poorly in Nebraska and Ohio. The interaction was described as unintelligible. Hattemer (1969) was not able to explain genotype x environment interactions in height growth of Japanese larch. This means that the tallest seedlots in one plantation may not be the best in other plantations.

However, Genys (1972) found that Maryland growth data were more strongly correlated to data from Germany than to data from north-central United States. His study was based on 16 different seed sources.

Diameter Growth 1 Ft. Above Ground

There were significant (1 percent level) differences in diameter growth among the 22 seed sources (table 2). No geographic pattern was observed. The rank correlation coefficients between the diameter and origin data were weak.

The range in seedlot means varied from 9.5 to 12.9 cm, a difference of 36 percent. This range was far smaller than that observed at the two Maryland test plantations (Genys 1972). However, Genys' and my data are similar in one respect--both have established a strong positive height-diameter correlation (r = 0.720 in my study). The two growth traits may be inherited together.

The between-seedlot differences in the height-to-diameter ratios (cm/cm) were significant at the 5 percent level (table 2). A seedlot having a high h/d ratio is more desirable because it has less stem tamper.

The h/d ratios were correlated with the 1971 height and diameter. Both correlation coefficients were insignificant (r = 0.170 and -0.297, respectively).

DIFFERENCES IN WOOD QUALITY

Specific gravity and tracheid length are the most extensively studied wood properties, both are under moderate to strong genetic control (Smith 1967, Zobel 1961); thus, significant gains can be expected through selection breeding. The wood characteristics of Japanese larch are not well known and information based on rangewide material is not available.

Use of increment core sample extracted at the breast height or stump height (1 foot above ground) has been a common practice for the evaluation

of wood quality. However, whether the entire increment core (pith to bark) or portion of the core should be used is not known. I found that a single growth increment formed during the same growing season was adequate to show the geographic variation pattern.

The stump height (or breast height)-whole tree values relation was not determined. However, there are numerous studies for pines that indicate a strong correlation between the two values (Wahlgren and Fassnacht 1959).

Specific Gravity

The between-seedlot differences were significant at the 5 percent level (table 2). A single seedlot (Schmalenbeck No. 23) from Mt. Komaga had a higher specific gravity than those from the rest of the species range.

There was no clearcut geographic variation pattern in specific gravity; the correlations between specific gravity and origin data were weak (the rank correlation coefficients were from 0.044 to 0.326). Heavy wood may be characteristic of seedlots from northern as well as from southern localities, or from both high and low altitudes.

Nor was there a significant correlation (r = 0.031) between specific gravity and height growth measured in 1971, 10 years after planting. This is similar to loblolly pine (*Pinus taeda* L.), for which Matziris and Zobel (1973) attributed only 7.3 percent of the total variation in specific gravity to growth rate (r = 0.271 with 353 degrees of freedom). Selection of fast growing seedlots may not be accompanied by a desirable wood quality. The specific gravity-diameter growth correlation was also nil (r = 0.003) in Japanese larch.

The overall mean for the trunkwood specific gravity was 0.398, comparable to that observed for loblolly pine (Matziris and Zobel 1973). In both studies, juvenile wood was used as the study material. The range in seedlot means varied from 0.366 to 0.441--a difference of 20 percent. This is equivalent to 75 kg more wood/m^3 (4.68 lbs/ft^3). The between-tree range was from 0.311 to 0.525, a difference of 69 percent. The greater between-tree variation was expected; it has been found in eastern white pine and European black pine growing in the same area in Michigan. The larger the variation among individual trees, the faster and more efficient improvement can be made through selection.

Tracheid Length

There were no significant differences in tracheid length among the 22 Japanese larch seed sources.

Bannan (1965) studied fiber morphology for members of several coniferous genera and concluded that species or races growing on favorable sites in general had longer fibers. Although the tracheid-height and the

tracheid-diameter correlations were statistically significant (1 percent level) in Japanese larch, they are of little practical importance. Mean tracheid length of the five tallest seedlots was only 0.04 mm longer than that of the five shortest ones.

Overall mean tracheid length was 2.07 mm. The seedlot means ranged from 1.98 to 2.17 mm, a difference of only 10 percent. The between-tree range was from 1.75 to 2.39 mm, a difference of 37 percent. Both ranges were much narrower than those of specific gravity.

The tracheid length-specific gravity correlation was weak ($r = 0.370$). This was also the case with a number of pine species such as loblolly pine (Jackson and Strickland 1962, Matziris and Zobel 1973), eastern white pine (Lee 1974) and European black pine (Lee and Wright 1975). The two wood properties may be inherited independently.

PRACTICAL APPLICATION

Based on my observations, seed sources from Mt. Nantai in the north-eastern species range should be recommended for planting in the Lake States area. They are tall and grow at least 5 percent taller than the plantation mean (647 cm at age 10 from planting). Trees from Mt. Nantai are efficient wood producers (table 2); they started growth early in the spring (the time of leafing not correlated with the latitude and altitude of seed source according to Yanagisawa 1961), tended to shed off their leaves early, and suffered little damage from winter cold (Farnsworth *et al*. 1972). Schönbach *et al*. (1966) indicated that the resistance to early autumnal frost was closely associated with time of growth cessation. Mt. Nantai is located at a northern latitude; thus, trees from that area lignify early which contributed to frost-damage being less than that found in trees from more southerly seed sources (Yanagisawa 1961). The wood quality of trees from Mt. Nantai is average. Genys (1972) reported that trees from Mt. Nantai are not as susceptible to larch sawfly and offer better stem quality (straightness) when compared to trees growing further south.

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TEN-YEAR PERFORMANCE OF DOUGLAS-FIR PROVENANCES IN EASTERN NEBRASKA

Ralph A. Read and John A. Sprackling[1/]

ABSTRACT--Seedlings from 55 seed sources were established in a field test as 1+1+1 potted transplants on a silt loam soil near Plattsmouth, Nebraska. Mortality was 76 percent in the nursery the first year, increased to 89 percent for potted seedlings the second year, and reached 98 percent 1 year after field planting. All coastal types died and survival was low for north-central provenances. Arizona and New Mexico seed sources gave the best survival (20 percent). Height-latitude correlation was $r = 0.81$, southern Colorado, New Mexico, and Arizona seed sources grew best. Some north-central provenances have grown well in recent years. Spring growth flush is earlier in southern than in northern material. The pattern agrees with the spring frost pattern in Michigan: southern sources are damaged while northern sources are not. In Nebraska the southern material suffered fall frost damage perhaps as a result of delayed growth cessation. A Durango, Colorado, provenance is recommended for landscape, greenbelt, and Christmas tree plantings in eastern Nebraska. A Mt. Lemmon, Arizona, provenance is recommended for Christmas trees in eastern Nebraska sites protected from spring frosts and winter winds.

Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) is the most important commercial timber tree in the United States. In this paper, however, we speak of Douglas-fir not for timber purposes but as a tree for the enhancement of the environment and for use as Christmas trees. The Great Plains region of North America needs conifers for protection and for ornamental purposes, and Douglas-fir trees can help fulfill these needs in selected locations if the source of the seed is carefully chosen.

A study to identify better adapted seed origins of trees for planting in the central Great Plains is being conducted as part of the Cooperative Regional Tree Improvement Project (NC-99) of the North Central States Agricultural Experiment Stations. Credits go to Jonathan W. Wright, Professor of Forestry, Michigan State University for initiating the study

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and providing planting stock, and to Walter T. Bagley, Associate Professor, Department of Forestry, University of Nebraska, for cooperation in planting and maintaining the plantation.

PAST RESEARCH

Douglas-fir has been successfully introduced in Europe. The interior (Rocky Mountain) variety has been planted in mountainous areas with severe climates and the coastal form restricted to milder climates of England and parts of Germany (Frothingham 1909). In the United States, rangewide provenance tests east of the Rocky Mountains have consistently revealed that West Coast origins are highly susceptible to winter damage and that trees from southern Rocky Mountain origins grow fastest.

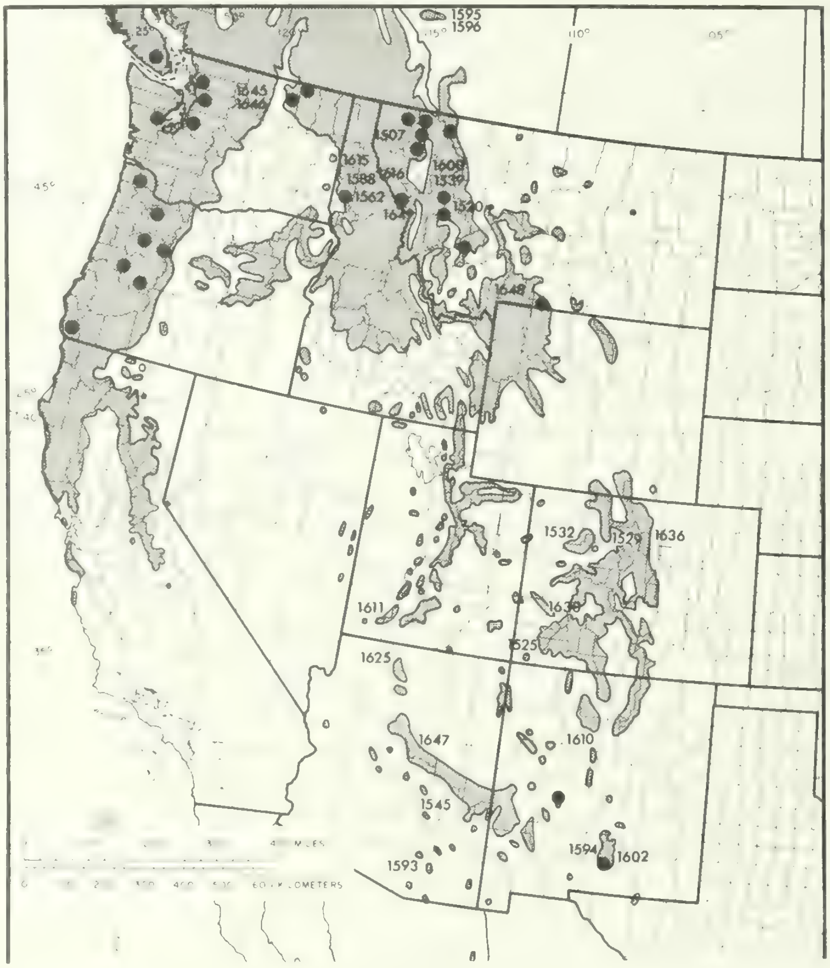

Figure 1.--Natural distribution of Douglas-fir, and provenances tested in eastern Nebraska. Origin numbers denote those that have survived black circles, those that died in the first 3 years (Little 1971)

Geographic patterns of variation within the range of the species (fig. 1) have been recognized but there is some lack of agreement on them. Frothingham (1909) divided the range into five silvical regions: (1) North coast, (2) Sierra, (3) Northern Rockies, (4) Central Rockies, and (5) Southern Rockies. The first two comprise the area known as var. menziesii, and the other three are in the regions of var. glauca.

Wright et al. (1971) delineated 8 to 10 geographic areas based on performance in 3- to 8-year-old provenance plantations in Michigan and Nebraska. Some of these groups were similar to Frothingham's pattern and others were not. Arizona and New Mexico sources grew tallest and had bluer foliage at 8 years of age, but were damaged by winter cold in the Michigan plantings. Origins from west of the Cascades suffered extreme winter damage, and practically all of them died in the nursery.

Heit (1968) recognized three separate forms of Douglas-fir based on a New York nursery study of seedlings from range-wide sources. He referred to a Pacific Coast form viridis (now var. menziesii); a continental inland form caesia (presumably northern Idaho, Montana, and northern Wyoming); and a lower Rocky Mountain form glauca (remainder of range from central Rockies southward). Heit found, that of 11 interior origins, those from Coconino National Forest, Arizona, and the Carson National Forest, New Mexico, grew fastest and had the bluest foliage. A Montana origin of the Lewis and Clark National Forest grew slowest, and Colorado origins had average growth. He concluded that southern origins grew later into the summer when annual growth ceased for others, and that frost damage to these origins as seedlings was light and temporary because they grew normally the following season without any apparent leader deformity.

A Pennsylvania test of 19 origins from the Pacific Coast to the Rockies resulted in 55 percent mortality in western Washington and Oregon origins, compared to 21 percent for those from Colorado and New Mexico. Yet growth rate of surviving Pacific northwest trees slightly exceeded that of interior origins. Late spring frosts damaged interior origins, but they recovered rapidly and grew well (Byrnes et al. 1958).

Gerhold (1966) tested 67 of Wright's origins in a nursery near Potters Mills, Pennsylvania. West Coast origins were severely damaged by winter cold but the survivors were tallest of all origins at age 3. As in Wright's study, the Arizona and New Mexico origins outgrew other interior origins but suffered more winter injury.

Past studies all seem to indicate that the natural range of Douglas-fir in the United States is composed of the following groups: (1) Pacific Coast, (2) northern Rockies (and Wright's inland Empire), (3) central Rockies, and (4) southern Rockies. Moreover, all studies appear to indicate that the Pacific Coast variety does not survive east of the Rockies, and that the southern Rocky Mountain origins grow fastest.

The performance of Douglas-fir origins in eastern Nebraska reported here updates the first report by Wright et al. (1971) of the 55 origins tested in Nebraska, with 5 additional years' growth, and new information on spring growth flushing and winter damage to terminals.

METHODS

Seeds were collected from 128 natural stands throughout the range of the species in United States and Canada and sown in spring 1962 in a Michigan State University nursery near East Lansing. One year later, 30 to 60 seedlings each of 55 origins were sent to Lincoln, Nebraska, where they were lined-out in a holding bed (table 1). In spring 1964, the 1+1 transplants were dug, potted, and lined-out again at the same location to increase their size.

In spring 1965 they were field planted as 1+1+1 stock at the Horning State Farm near Plattsmouth, Nebraska. The plantation is located on a ridge top of silt loam derived from loess, at 41°N,96°W, and 1,100 feet elevation. Growing season averages 170 days and mean annual precipitation is 30 inches; 75 percent falls during the growing season. Seedlings were planted in one-tree plots at a spacing of 12 by 12 feet Eastern redcedar (*Juniperus virginiana*) fillers were planted for early protection between each Douglas-fir in the rows (but not between rows) to give a spacing of 6 by 12 feet.

The site was cultivated 1 year before planting, and Simazine 80W at 4 lbs per acre was sprayed on both sides of each tree row after planting to control weeds, and for 5 years thereafter. The plantation was mowed between rows during the growing season. The trees were checked several times each year for insects, diseases, and other injury. Heights were measured annually from 1966, except for 1972. The eastern redcedar fillers were removed in spring 1974 to prevent excessive crowding.

Trees were rated on two dates in spring 1974 and on four dates in spring 1975 as to the developmental stage of buds and growth of new shoots and needles. Each tree was given a phenology rating on a scale of 1 to 5, ranging from dormant buds to well advanced shoot and needle growth. An estimate of the sequence in which the different origins start spring growth was obtained by using the ratings of the one date each year that showed the greatest spread in values.

Average needle length was computed from five measurements of needles collected from lateral branches on the south side of each tree, and cone production was evaluated by counting all cones in August 1975.

Table 1.--Data on seed origin locations of Douglas-fir tested in eastern Nebraska

COAST VAR. MENZIESII

Michigan State Univ. origin No.	State or Province	Place	North latitude	West longitude	Elevation
			Degrees	Degrees	Feet
1634	VAN	Cowichan L.	48.8	124.0	600
1620	WA	Camano	48.2	122.3	50
1617	WA	Granite Falls	48.1	122.0	600
1623	WA	Enemclaw	47.2	122.0	1,308
1627	WA	Shelton	47.2	123.4	320
1624	OR	Jewell	45.8	123.4	700
1621	OR	Molalla	45.2	122.2	100
1618	OR	Cascadia	44.4	122.7	800
1585	OR	Sisters	44.3	121.8	3,500
1622	OR	Cottage Grove	43.8	123.0	675
1613	OR	Oakridge	43.7	122.5	3,000
1619	OR	Brookings	42.0	124.2	162
*1645	WA	Fish Lake	48.6	119.7	2,000
*1646	WA	Buck Mtn.	48.4	119.8	5,000
ROCKY MOUNTAIN VAR. GLAUCA (WEST OF CONTINENTAL DIVIDE)					
1556	WA	Curlew	48.9	118.8	4,100
1651	WA	Omak	48.6	119.5	2,500
*1615	ID	Coeur d'Alene	47.7	116.8	2,400
*1588	ID	Wallace	47.5	116.0	3,000
*1562	ID	Clarkia	47.0	116.1	4,500
1573	ID	Moscow	46.6	116.8	2,500
*1507	MT	Libby	48.4	115.5	3,800
1517	MT	Libby	48.4	115.2	4,000
1650	MT	Whitefish	48.5	114.7	3,500
1519	MT	Whitefish	48.4	114.7	4,000
1521	MT	Kalispell	48.2	114.5	3,000
*1600	MT	Spotted Bear RS	48.0	113.0	3,680
*1616	MT	St. Regis	47.5	115.2	4,000
1603	MT	St. Regis	47.2	114.8	5,000
*1649	MT	Missoula	47.0	114.0	3,500
1504	MT	Missoula	47.0	113.8	6,000
*1520	MT	Greenough	46.9	113.4	4,000
1506	MT	Salmon Lake	47.2	113.2	5,000
*1539	MT	Big Prairie RS	47.3	113.5	4,600
1518	MT	Stevensville	46.5	114.2	4,500
1606	MT	Butte	46.0	112.5	6,500

Table 1 continuted on next page

Table 1. continued

ROCKY MOUNTAIN VAR. GLAUCA (EAST OF CONTINENTAL DIVIDE)

Michigan State Univ. Origin No.	State or Province	Place	North latitude	West longitude	Elevation
			Degrees	Degrees	Feet
*1595	ALB	Kananaskis	51.0	115.0	4,500
*1596	ALB	Kananaskis	51.1	115.0	5,000
1513	MT	St. Mary	48.8	113.5	4,480
*1648	MT	Big Timber	45.5	110.0	6,000
1503	MT	Absarokee	45.5	109.4	5,600
ROCKY MOUNTAIN VAR. GLAUCA (CENTRAL AND SOUTHERN ROCKIES)					
*1636	CO	Boulder	40.2	105.5	8,650
*1529	CO	Kremmling	40.0	106.5	8,000
*1532	CO	Meeker	40.2	107.9	8,200
*1630	CO	Ouray	38.2	107.6	9,100
*1525	CO	Durango	37.5	107.8	8.500
*1610	NM	Jemez RD	35.5	106.8	8,500
1546	NM	Magdalena	34.2	107.2	8,200
*1594	NM	Cloudcroft	33.0	105.8	8,670
*1602	NM	Mayhill	32.9	105.4	7,000
1614	NM	Sacramento Mtns.	32.7	105.7	8,300
*1611	UT	Panguitch	37.6	112.5	8,250
*1625	az	Fredonia	37.0	112.5	9,000
*1647	AZ	Long Valley	34.7	111.0	7,000
*1545	AZ	Globe	33.3	110.7	7,800
*1593	AZ	Mt. Lemmon	32.4	110.8	8,400

* Origins for which subsequent data are given in table 2; all other origins failed.

RESULTS AND DISCUSSION

Survival

The number of surviving trees from many of the northern origins was only one or two; this naturally limits the confidence one can place on growth performance, and should be considered when the results are interpret

Mortality in the temporary lineout beds at Lincoln was 76 percent the first year. At the end of the second year as potted seedlings, total mortality had increased to 89 percent. All seedlings of Coastal western Washington and Oregon origins died during the first 2 years. Three years

after field planting in 1968, mortality had reached 98 percent. Only 2 percent of the seedlings from northern Idaho, western Montana, eastern Washington, and Alberta, Canada, origins survived after 3 years in the field (table 2).

Table 2.--Survival and height growth of Douglas-fir provenances in eastern Nebraska

Michigan State Univ. origin No.	Location	Surviving trees	Height growth: Mean ann. 1967-1974	Height growth: 10-year field	Height growth: Plantation mean
		No.	Feet	Feet	Percent
1539	Big Prairie, MT	1	0.3	2.7	25
1648	Big Timber, MT	1	0.3	2.9	27
1562	Clarkia, ID	2	0.4	3.3	30
1596	Kananaskis, ALB	1	0.4	3.9	36
1595	Kananaskis, ALB	1	0.5	4.6	42
1600	Spotted Bear, MT	1	0.6	5.1	47
1649	Missoula, MT	1	0.8	6.8	62
1636	Boulder, CO	7	0.8	7.1	65
1588	Wallace, ID	7	0.8	7.2	66
1529	Kremmling, CO	2	0.8	7.3	67
1615	Coeur d'Alene, ID	2	0.9	7.4	68
1520	Greenough, MT	1	0.9	7.6	70
1646	Buck Mtn. WA	1	1.0	8.0	73
1507	Libby, MT	1	1.0	8.0	73
1532	Meeker, CO	21	0.9	8.0	73
1611	Panguitch, UT	5	0.9	8.1	74
1616	St. Regis, MT	3	1.0	8.3	76
1645	Fish Lake, WA	4	1.0	8.8	81
1625	Fredonia, AZ	8	1.0	9.1	83
1630	Ouray, CO	1	1.1	9.4	86
1525	Durango, CO	8	1.0	10.8	99
1647	Long Valley, AZ	12	1.3	11.6	106
1610	Jemez, NM	28	1.5	12.9	118
1545	Globe, AZ	4	1.4	12.9	118
1594	Cloudcroft, NM	8	1.5	13.0	119
1602	Mayhill, NM	34	1.6	13.5	124
1593	Mt. Lemmon, AZ	13	1.8	15.8	145

Survival of central and southern Rocky Mountain origins was 20 percent. Arizona and New Mexico origins had the best survival.

The excessive mortality of coast and northern Rocky Mountain origins in the first 2 years was probably because they were smaller than stock normally planted in the Plains region. Douglas-fir planting stock is usually not transplanted until seedlings are 2 years old. They are then grown another 2 years as transplants before field planting. Past experience in field planting Colorado sources in the Plains has shown that much higher survivals can be obtained if stock is 2+2.

Height and Growth Rates

Heights and growth rates (table 2, figs. 2 and 3) were correlated with latitude; trees from the southern origins grew faster than those from northern origins. Regression analysis using individual trees as a basis indicated that latitude accounted for 21 percent of the variation in tree heights. Correlation of height and latitude using origin means was $r = -0.81$.

Growth curves grouped by geographic areas show that for 5 to 6 years after planting the central and northern Rocky Mountain origins (the seven lowest curves on fig. 3) grew very slowly, but have since shown a gradual acceleration in growth. This contrasts with the performance of various pine provenance tests at the Horning farm, which normally increase their growth rate in the third year. At first the Douglas-fir planting site was open and exposed, but as redcedar filler trees and adjacent species developed, the plantation was protected from wind during both winter and summer.

All New Mexico and Arizona origins have grown rapidly since planting. Trees from Globe, Arizona, (#1545) grew fastest through 1969, but since that time have suffered winter injury and repeated loss of terminals. Mt. Lemmon, Arizona, (#1593) trees surpassed the Globe source and remained the tallest origin to date, averaging 15.8 feet.

Foliage Characteristics and Form

Needle lengths varied among and within origins, but showed no correlation with rate of height growth or latitude (table 3). Several New Mexico and Arizona trees had bluish-green foliage, but none of these origins was consistently blue-green, as reported by other investigators. Northern Rocky Mountain trees had green foliage. Branch angles, foliage densities, and compactness of crowns varied among trees within the same origin, making it impossible to recommend any particular source for its inherently superior aesthetic value.

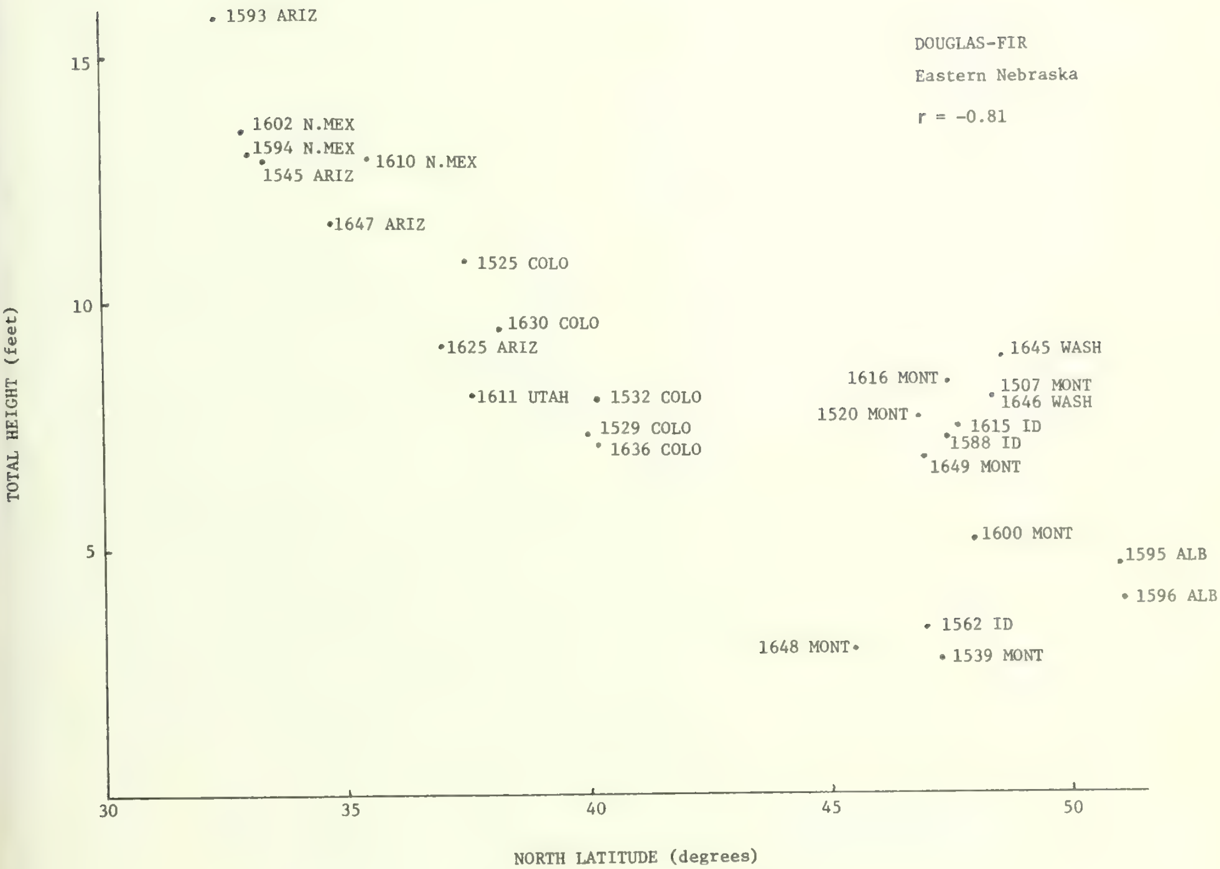

Figure 2--Correlation of 10-year field height with latitude of origin, in eastern Nebraska.

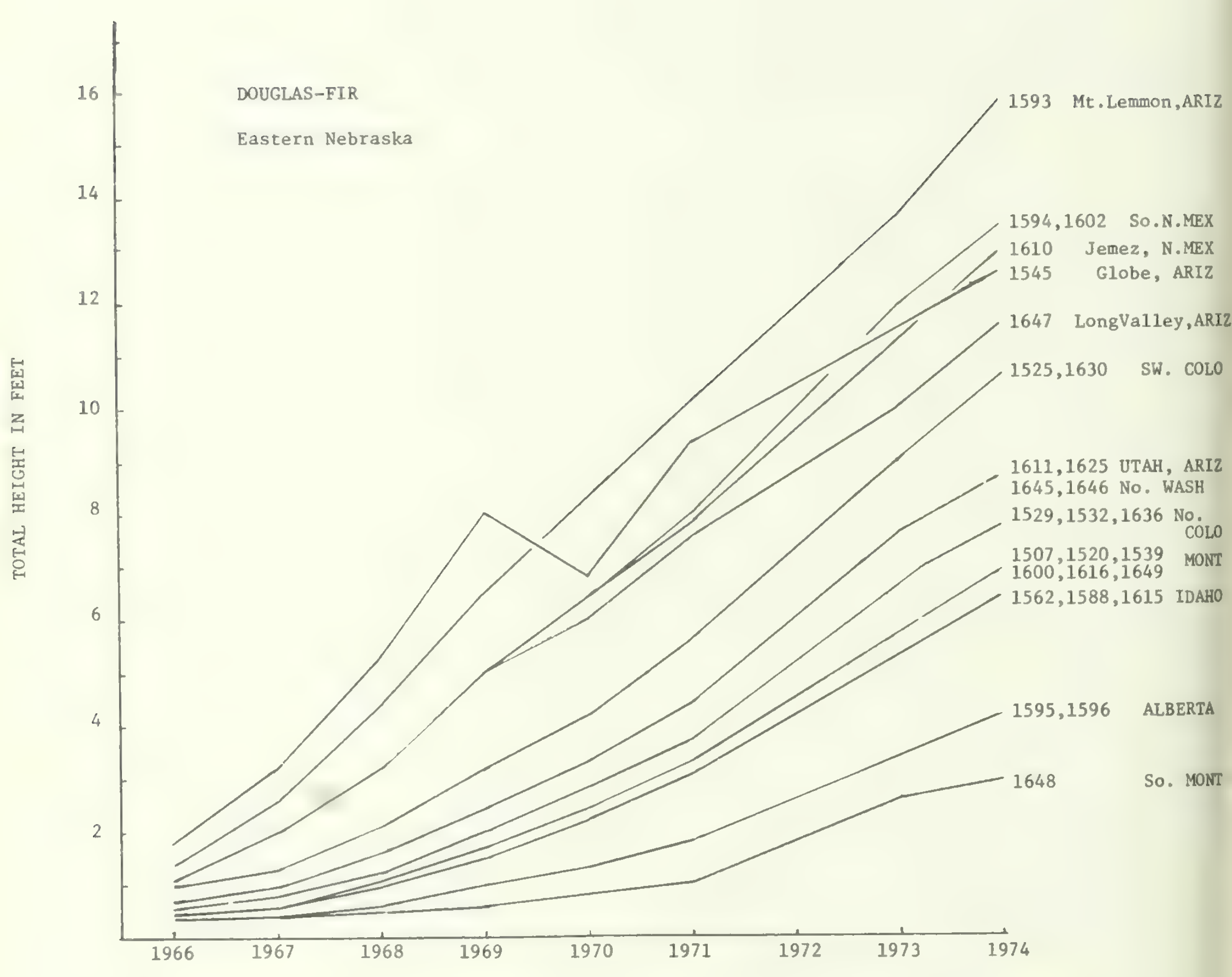

Figure 3.--Growth curves of origins (some grouped together) in the 10-year field test in eastern Nebraska.

Table 3.--Needle length, spring flushing, and terminal dieback on Douglas-fir provenances in eastern Nebraska

Michigan State Univ. origin No.	Location	Average needle length	Spring growth flushing May 9, 1974	Spring growth flushing May 12, 1975	Trees with terminal die back
		mm.	Code1/		Percent
1595	Alberta	26	2.0	1.5	
1596	Alberta	25	3.0	1.5	
1507	W. Montana	28	1.0	1.5	
1616	W. Montana	28	1.7	1.0	
1600	W. Montana	28	2.0	1.0	
1649	W. Montana	28	2.0	3.0	
1520	W. Montana	28	2.0	2.0	
1539	W. Montana	31	3.0	2.0	
1588	N. Idaho	32	2.0	1.5	
1615	N. Idaho	32	2.8	1.8	
1562	N. Idaho	28	2.8	1.5	
1648	S. Montana	25	3.0	2.0	
1645	NC.Washington	32	2.9	2.0	25
1646	NC.Washington	27	4.0	3.0	
1532	N. Colorado	27	3.9	2.8	5
1636	N. Colorado	25	4.3	2.7	
1529	N. Colorado	24	4.8	3.0	
1611	S. Utah	30	3.2	2.3	
1625	N. Arizona	27	3.2	2.2	25
1630	SW.Colorado	33	2.0	1.0	
1525	SW.Colorado	34	4.5	3.5	
1610	N. New Mexico	29	3.5	2.8	39
1602	S. New Mexico	30	3.5	2.6	30
1594	S. New Mexico	32	3.8	2.8	38
1647	NC.Arizona	32	4.6	3.2	58
1545	SC.Arizona	40	4.4	3.4	100
1593	S. Arizona	30	4.1	2.9	38

1/ 1.0 = latest; 5.0 = earliest.

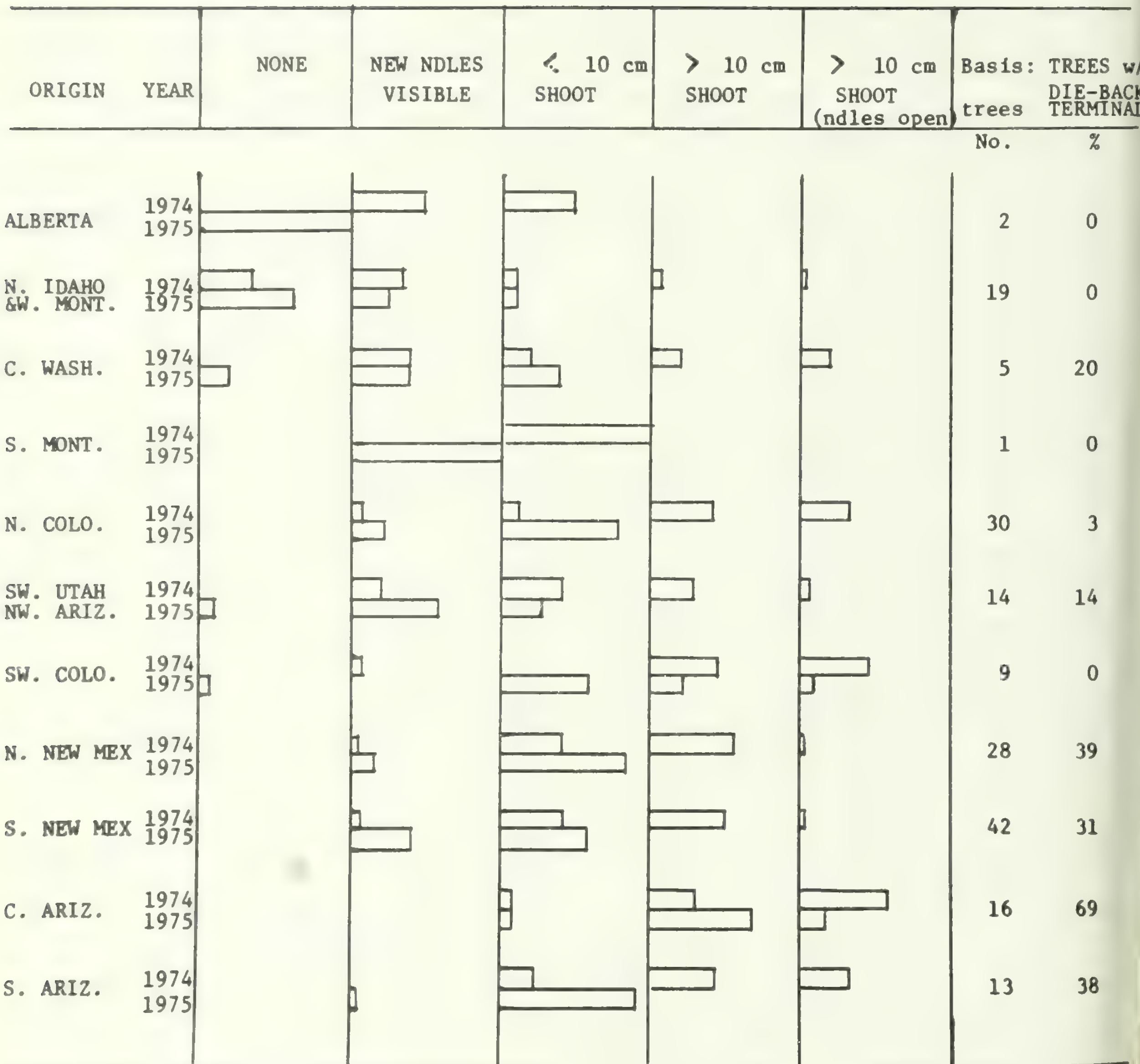

Figure 4.--Spring growth flushing 1974 and 1975 by origins and percent of trees affected by terminal dieback.

Spring Growth Flush

Bud bursting and subsequent shoot and needle development showed widest variation by origin on May 9, 1974, and on May 12, 1975. New shoot and needle development were well advanced on most Arizona and New Mexico origins, at the same time many of the northern origins were still dormant or just beginning to flush (table 3 and fig. 4). Colorado origins tended to be intermediate. This was consistent for the 2 years, 1974 and 1975, although different spring temperature patterns in 1975 resulted in a narrowing of the rating values compared to 1974.

Steiner and Wright (1975) found this same relation in a Kellogg, Michigan, plantation at 12 years of age. Arizona, New Mexico, and Colorado origins leafed out early and were highly susceptible to late spring frost, whereas origins from western Montana and northern Idaho leafed out a month later and were not susceptible.

Munger and Morris (1936) recorded the same bud bursting activity in 13 Coastal sources of Douglas-fir, west of the Cascade Range and extending over only 3-1/2° latitude from northern Washington to central Oregon. Bud bursting was earliest on the southerly and low elevation sources, and latest on those of northern Washington.

Another point of interest is the apparent similarity in phenology of the central Washington origins with those further south in the central Rocky Mountains, rather than with origins much closer in northern Idaho and western Montana (fig. 4). Frothingham's distribution of silvical regions shows the eastern side of the Cascades through Washington in the same silvical region as the central Rockies.

These observations indicate that Douglas-fir phenology at this Nebraska latitude (41°) as related to latitude of origin, is the reverse of ponderosa pine. In a central Nebraska nursery experiment, the northern origins of ponderosa seedlings from central and eastern Montana began spring growth several weeks before origins from New Mexico (Read 1975). Despite the early growth flush of southern origin Douglas-fir in Nebraska, no damage from late spring frost has yet occurred. This is because the ridge top plantation site is sufficiently exposed to delay extremely early bud bursting and to prevent frost pockets.

Terminal Dieback

Differences in time of bud set and cessation of terminal growth were not measured. However, a possible result of differences in time of growth cessation, has been dieback of the terminals on 44 trees (about 40 percent) of the southern origins. Every Arizona and New Mexico origin showed damage on some trees, ranging from 25 percent of #1625, Fredonia, Arizona, to 100 percent of #1545 Globe, Arizona, (table 3, figs. 3 and 4).

Trees of southern origins do not cease growth early enough to avoid frost damage in late fall. This agrees with Wright et al. (1971) who found that among interior origins growing in Michigan and Pennsylvania, southern origins set buds latest, and therefore were winter damaged, while northern origins set buds earliest and were not injured.

Campbell and Sorensen (1973) found this same relation among West Coast origins of Douglas-fir, covering only 5 degrees spread in latitude from southern Oregon to northern Washington.

It is interesting that terminal dieback did not occur until these trees were 5 to 6 years old and averaged around 7 feet in height. Increased exposure of tops to winter winds may increase susceptibility, as it was noted that dieback increased significantly during the first winter after removal of the filler trees. Winter dieback has not yet caused mortality despite its recurrence on the same trees in successive winters. Strong lateral branches grow into dominant terminals the following growing seasons (fig. 5).

Cone Production

First cones were observed in August 1975, after 11 years in the field. No measure of seed production and viability is yet available.

Six of 13 trees of the Mt. Lemmon, Arizona, source had cones ranging from 2 to 75 per tree, with a median of 7 to 8 cones. Two of 28 trees of the Jemez, New Mexico, source had 3 to 5 cones, and one of 4 trees of the Fish Lake, Washington, source had 13 cones. Initial cone production was strongly related to the tallest and largest crown trees in the plantation.

CONCLUSIONS AND RECOMMENDATIONS

This provenance test indicates that within the interior (Rocky Mountain) Douglas-fir var. glauca, there are large variations in survival, growth, and susceptibility to cold, which are strongly correlated with latitude of origin. Pacific Coast origins var. menziesii, cannot survive Nebraska winters. Northern Rocky Mountain origins have low survival rates and grow slowly. Therefore, northern Rockies and Pacific Coast origins of Douglas-fir are definitely not recommended for planting in Nebraska. Southern Rocky Mountain origins survive well and grow very fast, but individual trees suffer some cold injury. Central Rocky Mountain origins have average survival and growth, yet are not affected by cold temperatures.

Figure 5.--A #1647 central Arizona tree showing recovery from terminal dieback of the previous winter.

Douglas-fir can be grown with greatest success in eastern Nebraska, although with irrigation it probably can be grown further west in the State. Planting stock for maximum survival should have at least 8 to 12 inches top height and a fibrous root system of similar size; these will normally be 2+1 or 2+2 age class from the best nurseries. Younger potted stock may be satisfactory.

Major uses of this species in central Great Plains are for ornamental plantings and for Christmas trees. Therefore the slower growing, but winter hardy central Rocky Mountain origins may prove most successful in the long run. The Durango, Colorado, origin #1525, which has above average survival, medium growth, and no winter damage, is well adapted for landscape plantings, Christmas trees, greenbelts, and roadside parks. Central Rocky Mountain origins are not recommended for windbreaks because faster growing species of pine and juniper which give protection in fewer years, are available for this purpose.

Because of terminal dieback, the faster growing Arizona and New Mexico origins of Douglas-fir are the only ones recommended for Christmas trees. These short rotation tree crops should be a safe investment, because the winter killing of terminals in the Horning plantation did not occur until trees exceeded merchantable Christmas tree height. In planting these southern origins, it is essential to select plantation sites to avoid frost pockets where spring frost damage could occur, and wind swept areas where terminal dieback could be serious. The Mt. Lemmon, Arizona, source #1593 is recommended for Christmas tree growers in eastern Nebraska. These trees averaged 6.5 feet in height after only 5 years in the test plantation. Use of this fast growing origin will give Christmas tree growers a more rapid return on investment than slower growing trees.

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IMPROVED STRAINS OF DOUGLAS-FIR
FOR THE NORTHEASTERN UNITED STATES

Donald H. DeHayes and Jonathan W. Wright[1]

ABSTRACT.--Provenances from the interior range of Douglas-fir were tested in Kalamazoo, Cass, and Osceola Counties, Michigan. Mortality, height growth, foliage color, spring frost damage, time of leafing out, and foliar moisture contents and drying rates were evaluated. Trees from Arizona and New Mexico (ARINEM race) grew fastest followed by trees from northern Idaho and northwestern Montana (INEMP). On good sites these provenances produced merchantable Christmas trees in 7-8 years. Trees from central Montana (CMON) and northern Colorado (NOROC) grew half as fast. NOCOL and SOCOL races suffered severe frost injury while ARINEM was moderately to heavily damaged. In contrast northern races (NOROC and INEMP) suffered relatively little damage. From the leafing-out data it was clear the correlation between leafing out and injury was significant. NOROC and INEMP races leaf out 2-3 weeks after the southern races and avoid frost damage. Also tall trees suffered relatively little damage. The Arizona provenance had the greatest foliar moisture content as well as the slowest rate of drying; and the ARINEM race was characterized by having the bluest needles of the material tested. Recommends ARINEM for Christmas trees where frost is no problem; where frost may occur provenances from northern Idaho may give better results. Using mixtures of the two races would reduce risk.

INTRODUCTION

Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) is one of the most widely distributed conifers in western United States and has great planting potential. It occurs naturally from Canada to Mexico and from the Pacific Cost to the eastern slopes of the Rocky Mountains. It has been successfully planted as an ornamental, Christmas tree or timber tree in many other parts of the United States.

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In the Pacific Northwest, Douglas-fir is recognized as one of the largest and most important timber trees. It towers up to heights as great as 300 ft and may reach 15 ft in diameter. In the northeastern United States it is planted mainly as an ornamental and Christmas tree. In Michigan over the past 25 years it has consistently commanded the highest prices in retail Christmas tree yards.

In most Christmas tree plantations established in Michigan in the early 1950's, the planting stock was grown from seed collected in northern Colorado and central Montana. Growth was so slow that 15 to 20 years were required for harvest. Early provenance tests in eastern United States (Baldwin and Murphy 1956; Gerhold 1966) showed that West Coast origins were not reliably hardy but that there was enough genetic variability with Rocky Mountain Douglas-fir to make possible appreciable improvement in planting stock for Michigan conditions.

This paper reports the results of a seed source experiment designed to result in dramatic increases in productivity of Douglas-fir planted in Michigan.

MATERIALS AND METHODS

In 1961 seeds were obtained from 129 natural stands of Douglas-fir (fig. 1) (Wright et al. 1971). The parental stands represented nearly the entire natural range of the species. The seeds were sown in an experimental nursery in East Lansing, Michigan in spring 1962. All the west coast seedlots suffered such severe winter damage while in the nursery, that they were discarded without field planting.

In spring of 1965, 68 seedlots from the interior portion of the range were field planted as 2 + 1 stock in 3 permanent test plantations in southern Michigan. In each plantation a randomized complete block design with 10 replications and 4-tree plots was used. Spacing was 6 by 6 ft. Weed control was achieved by the application of amino-triazole (2 gal/acre) the fall before planting and by simazine (4 lb/acre) immediately after planting. Details for individual plantations are as follows:

W. K. Kellogg Forest, Augusta, Kalamazoo County, Michigan, 65 miles southwest of East Lansing; site a level hilltop with good air drainage; soil sandy loam; 67 seedlots; mortality 8 percent by 1973.

Fred Russ Forest, Decatur, Cass County, Michigan, 110 miles southwest of East Lansing; site a level field with poor air drainage; soil sandy loam; 19 seedlots; mortality 21 percent by 1973.

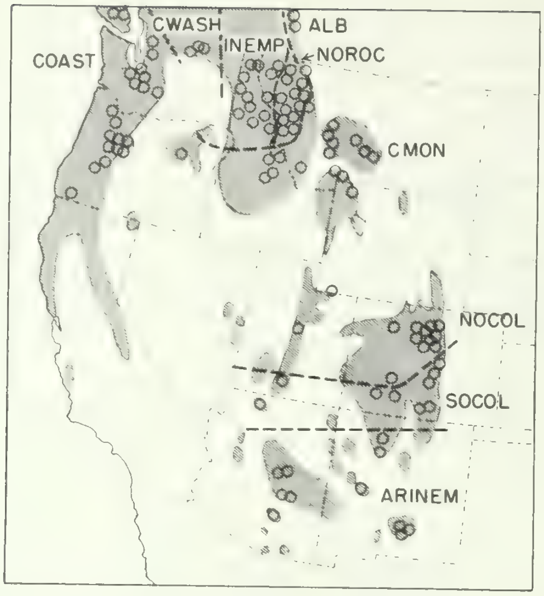

Figure 1.--Natural range of Douglas-fir (shaded area) and location of stands (dots) from which seed was collected and grown in Michigan. Douglas-fir races as recognized by Wright et al. (1971) are indicated.

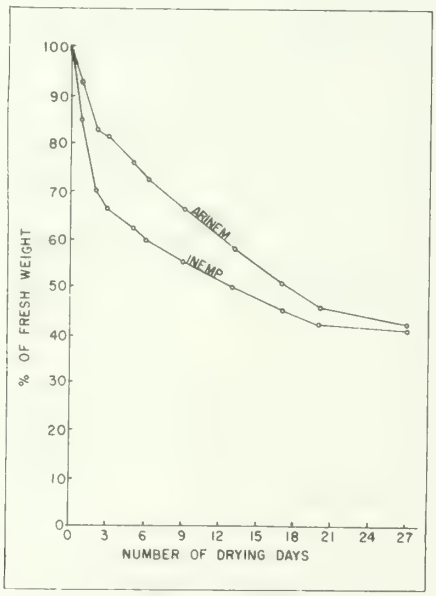

Figure 2.--Differences in rates of moisture loss of cut branches of Arizona-New Mexico (ARINEM) and northern Idaho (INEMP) Douglas-fir races growing at Kellogg Forest in southern Michigan.

Camp Kett (Kettunen Center), Tustin, Osceola County, Michigan, 150 miles northwest of East Lansing; site rolling with 5-20 percent north slopes and good air drainage, soil sandy loam; mortality 25 percent by 1973.

In all plantations, mortality, height, foliage color, and damage from late spring frosts were measured two or three times, the last time in the summer of 1973. Time of leafing out and rate of foliar drying were measured in the Kellogg Forest plantation in May and August 1973, respectively. Foliar moisture content was measured in the Kellogg Forest and Camp Kett plantations in August 1973.

Foliar moisture content was measured for both current-year and year-old foliage. Foliage samples (10 to 45 g/plot) were removed from all living trees in each plot. All material collected from a plot was combined and placed in a labelled, tared paper envelope and then sealed in a tared plastic bag to prevent moisture loss. Samples were returned to the laboratory for weighing within 24 hours and were subsequently oven dried at a temperature of 70°C. Dry weights were determined after the tissue reached a constant oven dry weight over a 24-hour period. Occasional technique checks indicated less than 0.1 percent error in fresh weight due to moisture loss prior to weighing.

Rate of foliage drying was determined by removing one 2-to-3-ft. branch per tree from each of two seedlots of Arizona and Northern Idaho origin. Samples were collected from 30 trees representing 2 replicates of the Kellogg Forest planation. Immediately after collection the branches were placed in sealed plastic bags and within 4 hours were brought to the laboratory where their fresh weights were determined. They were then spread out to dry in a laboratory kept at 22°C.

RESULTS

For the purpose of comparison and clear presentation, the 68 seedlots were divided into 8 geographical races and given code names according to the classification of Wright et al. (1971) (fig. 1). They divided the seedlots into races because they discovered that most genetic variation existed between groups of seedlots from different geographic locations. In other words, variation among seedlots within a race was very small whereas that between races was very large. The races and their distribution are as follows:

ALB ---------- Alberta

CMON --------- Central Montana, Wyoming

NOROC -------- Northern Rockies, West Central Montana

INEMP --------- Inland Empire, Northern Idaho and Northwestern Montana

CWASH --------- North Central Washington

NOCOL --------- Northern Colorado and adjacent Utah

SOCOL --------- Southern Colorado and adjacent Arizona

ARINEM -------- Central and Southern Arizona and New Mexico.

Mortality

By 1973 mortality averaged 8, 21, and 25 percent in the Kellogg, Russ, and Camp Kett plantations, respectively. The differences were presumably related to the effectiveness of weed control. Most deaths occurred during the first two years after field planting with only 1 to 2 percent additional mortality in the following 7 years. Mortality rates were similar for all races.

Height

At age 9 from planting, average heights were 7.4, 3.2, and 5.3 ft. in the Kellogg, Russ, and Camp Kett plantations, respectively. Slow growth in the Russ plantation is probably due to its location on a flat, open site subject to late spring frosts and strong westerly winds.

In all plantations trees grown from seed collected in Arizona and New Mexico (ARINEM race) grew fastest (table 1). They averaged 10.5, 4.3, and 6.8 ft tall at Kellogg Forest, Russ Forest, and Camp Kett, respectively at age 9 from planting. The INEMP race (northern Idaho and northwestern Montana) was second fastest growing, averaging 8.8, 3.8, and 5.6 ft tall, respectively, in the three plantations. Differences among individual seedlots within these races were not statistically significant.

Thus on good sites either of these races grew fast enough to produce merchantable Christmas trees on 7 or 8 year rotations. In sharp contrast, the CMON (central Montana) and NOCOL (northern Colorado) races grew only 50 to 60 percent as fast. Some trees of those races were still only 2 ft tall 9 years after planting.

Frost Susceptibility

Douglas-fir is subject to damage from late spring frosts. The amount of damage depends on the date and severity of the frost, and site conditions to which Douglas-fir is exposed. Killing frosts have occurred in Michigan when the temperature in the plantation falls below 28°F

Table 1.--Relative height of Douglas-fir (9 years old from planting) from different geographic origins growing at 3 test plantations in southern Michigan

Region of origin	Kellogg Forest	Russ Forest	Camp Kett
	Height Expressed as Percent of INEMP Trees		
Northern Races			
ALB	74	--	--
CMON	72	--	54
NOROC	91	92	89
CWASH	80	71	93
INEMP	100 (8.8 ft)[1/]	100 (3.8 ft)	100 (5.6 ft)
Southern Races			
NOCOL	59	63	73
SOCOL	88	63	88
ARINEM	119	113	120

1/ Figures in parenthesis are actual mean heights of INEMP trees.

($-2^{o}C$) after the trees have begun growing in the spring. Such frosts have occurred in our Douglas-fir plantations in 3 out of the 10 years since the trees have been field planted. Damage from late spring frosts results in killing of new foliage and causes unsightly damage to susceptible trees.

Killing late spring frosts occurred at Kellogg and Russ Forests in 1968, at Kellogg Forest and Camp Kett in 1969, and at all three places in 1973. The damage was worst at Russ Forest, where only the most resistant seedlots escaped serious injury.

Despite very large differences in incidence of frost damage at the three test sites, there were consistent differences in relative amounts of damage of the various races (table 2). Trees from the southern part of the range consistently suffered the most damage. Trees belonging to the NOCOL and SOCOL races were especially hard hit; the effects of the frost damage were compounded by their relatively small stature. Many of these trees were so heavily damaged that they had scarcely recovered by 1975 even though 1974 and 1975 were frost free. The ARINEM race suffered moderate to heavy damage but grew fast enough to show complete recovery the following year.

At the other extreme, the fastest growing northern races (NOROC and INEMP) experienced relatively little frost damage. Even at Russ Forest few trees of those races were injured enough to affect their merchantability at Christmas time.

Table 2.--Racial differences in susceptibility to frost damage and time of leafing out for Douglas-fir growing in Michigan plantations

Region of Origin	Frost Damage: Kellogg (3 yr avg.)	Frost Damage: Russ (2 yr avg.)	Frost Damage: Camp Kett (2 yr avg.)	Time of leafing out 1/ Kellogg only
	Range in Percent of Buds Killed			
Northern Races				
ALB	21-30	--	--	Intermediate
CMON	10-20	--	21-30	Late
NOROC	10-20	40-55	10-20	Very late
CWASH	21-30	56-70	21-30	Intermediate
INEMP	10-20	40-55	10-20	Very late
Southern Races				
NOCOL	31-45	71-85	21-30	Early
SOCOL	31-45	71-85	31-45	Early
ARINEM	21-30	71-85	21-30	Early
Average	25	65	21	

1/ Leafing out data applicable for May, 1973 (Steiner and Wright 1974).

Time of Leafing Out

The data on time of leafing out taken in the spring of 1973 furnished a very good clue as to the mechanisms of frost resistance. Growth started nearly three weeks later in the NOROC and INEMP varieties than in those from the southern part of the range. Since the frosts occurred 2 to 3 weeks after the first flush of growth, the frosts damaged the new growth on early trees but left the unopened buds on the later races unharmed (table 2). Therefore, the lesser amount of damage in the NOROC and INEMP varieties is a case of frost avoidance rather than frost resistance *per se*.

The correlation between earliness and susceptibility to frost damage was not perfect, however, as there was a confounding effect of height. Even in early-flushing seedlots tall trees suffered relatively small amounts of damage in their upper crowns.

Foliar Moisture Content

For all seedlots, moisture content averaged about 10 percent lower for year-old than for current-year foliage. This was probably due to an increase in cell wall thickness and cuticular waxes as the leaves matured.

For foliage of a given age, there were also genetic differences in foliar moisture content. Seedlots from Arizona and New Mexico (ARINEM race) had the most succulent foliage, averaging 58 and 68 percent moisture in year-old and current-year foliage, respectively. In contrast, the foliar moisture content was 54 to 55 percent and 64 to 65 percent, respectively, for year-old and current-year foliage of northern Idaho (INEMP race), central Washington (CWASH race), and northern Colorado (NOCOL race) trees.

Drying Rate of Fresh Branches

In the drying rate experiment, fresh branches were cut from 30 trees representing two seedlots each from Arizona and northern Idaho. The branches were spread out on a laboratory bench and weighed at intervals of 1 to 6 days.

After 2 days the Arizona branches lost 17 percent of their original fresh weight versus 30 percent for the northern Idaho branches (differences significant at the 1 percent level). This large difference in drying rate continued so that the Arizona branches were moister than the northern Idaho branches at all times until the experiment was concluded (fig. 2).

The differences in drying rate were clearly reflected in the appearance of the foliage. After 8 days all the Arizona branches appeared fresh and green whereas nearly half the northern Idaho branches had brown foliage (table 3).

Table 3.--Percent of branches turning brown after drying for various times

Origin	3 Days	8 Days	11 Days	20 Days	27 Days
Arizona	0	0	11	39	88
Idaho	8	42	50	75	100

Foliage Color

Foliage color was measured at the Kellogg Forest only in September 1973, using grades of 0 (= greenest) to 20 (= bluest).

Within some 4-tree plots there were all extremes from greenest to bluest. However, there was a great deal of consistency from plot to plot so that individual seedlots could be characterized as different from others. Most of the color differences are due to protective waxes on the needles rather than to differences in pigments. The races could be characterized as follows:

ALB--------------- moderately blue, uniform

INEMP, NOROC ----- uniformly among the greenest

CMON, CWASH ------ dark green with occasional moderately blue trees

NOCOL ------------ intermediate blue-green, uniform

SOCOL ------------ moderately blue, but variable; most seedlots were moderately blue but some were indistinguishable from northern races

ARINEM ----------- uniformly among the bluest

PRACTICAL APPLICATION

Of the interior races of Douglas-fir which can be considered reliably hardy in Michigan, only the ARINEM and INEMP races grow rapidly enough to be recommended for Christmas tree planting. With those races, rotations of 6 to 9 years are possible, versus rotations of 10 to 20 years for trees from other regions.

If frost is not apt to be a problem, the ARINEM race is superior in most respects (table 4). It grows fastest and has the foliage characteristics most desired by Christmas tree buyers. Its slower drying rate alone, if advertised, would make it a preferred tree.

Table 4.--Comparison of characteristics of the two fastest growing races

Race	Height age 9	Rotation	Frost damage	Foliage Color	Foliage Moisture	Foliage Dry Rate
	ft	years				
ARINEM	10.5	7	Medium	Blue	High	Slow
INEMP	8.8	8	Light	Green	Low	Fast

However, the possibility of serious damage from late spring frosts cannot be ignored. Such frosts are apt to occur once every 3 or 4 years. When they occur, trees from northern Idaho are most likely to escape with such a small amount of damage that they are merchantable even in the year of the frost. Trees from Arizona and New Mexico will probably suffer enough damage to reduce their merchantability in the year of the frost but will probably recover well the following year.

Perhaps the best solution is to plant a mixture of these two races, thus obtaining the advantages of the ARINEM trees if frost damage is not serious while providing insurance against loss of a year's income if it is.

Throughout this paper we have treated the races as if they were genetically uniform and distinct from one another. That is undoubtedly not true, and there is probably a considerable amount of genetic variation within any one of the races. To date, however, it has not been possible to say which particular stands within a region produce the best seed. Thus for the present, we can only make general recommendations that the seed be collected in Arizona and New Mexico or in northern Idaho and northwestern Montana.

Since 1970 a growing number of eastern nurserymen have been aware of the advantages of Arizona-New Mexico trees and offer such stock for sale under the names "Coconino", "Apache", or "Kaibab", etc. A smaller number have stock of the INEMP race for sale, some of which is listed as "Shuswap Lake, B.C."; that origin seems similar to the seedlots from northern Idaho. One should avoid buying stock of unspecified origin, as some such stock is known to be grown from seed collected in parts of the range producing very slow-growing trees.

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PROVENANCE AND FAMILY VARIATION IN BALSAM FIR FROM MICHIGAN AND WISCONSIN

D. T. Lester, R. M. Jeffers, and J. W. Wright[1/]

ABSTRACT.--Variation in height, branching, and flushing was measured for wind-pollinated families from six provenances at age 11 in from one to four plantations. Seed collected at one location in the Lower Peninsula of Michigan produced trees that were 20 percent taller, had 40 percent more lateral branches in the top whorl, and had a flushing score 25 percent later than average. Variation among families within provenances was between 30 and 40 percent of respective provenance means. Both provenance and family effects were significant, but provenance effects were generally much larger. Provenance selection clearly would be worthwhile in the Lake States.

Balsam fir (*Abies balsamea* L.), a species widely distributed in North America and a major component of the boreal forest, has received little attention from tree breeders and geneticists. Although commonly harvested for pulpwood, balsam fir is rarely planted except for ornamental uses. Principal interest, from a genetic point of view, has been in the taxonomic status of the species and the morphologically similar Fraser fir (*A. fraseri* (Pursh) Poir.) and subalpine fir (*A. lasiocarpa* (Hook) Nutt.) (Boivin 1959, Zavarin and Snajberk 1972).

To determine patterns of geographic variation, seeds were collected in 1960 by R. G. Hitt of the University of Wisconsin. Initial sampling was in Michigan and Wisconsin as a part of a regional project on geographic variation in many forest tree species. The study was expanded in 1962 to include sampling of the species range.

The results reported here represent early performance of provenances for which seed was maintained separately by maternal parent. These results are intended to supplement the picture of geographic variation being developed from measurements on provenance plantings from range-wide sampling.

1/ The authors are, respectively, Assoc. Prof. of Forest Genetics, Dept. of Forestry, University of Wisconsin, Madison, Wisconsin; Plant Geneticist, USDA Forest Service, Institute of Forest Genetics, Rhinelander, Wisconsin; and Prof. of Forestry, Dept. of Forestry, Michigan State University, East Lansing, Michigan. Funds for this research were provided in part by each employing institution, and in part by the U.S. Dept. of Agriculture through regional project NC-99 "Improvement of Forest Trees Through Selection and Breeding."

MATERIALS AND METHODS

Six balsam fir stands in Michigan and Wisconsin were sampled (fig. 1). At each location, cones were collected from 10 trees located at least 100 feet apart. Seeds from each tree were stored separately at 2°C until sowing in 1963. Seedlings were grown for 3 years at the Trout Lake State Forest Nursery in north-central Wisconsin, then distributed to cooperators who established four plantations (A, B, C, and D) (fig. 1). Plantations A and B trees were field planted as 3-2 stock in 1969 and plantation C and D trees were field planted as 3-3 stock in 1970. Plantations A and D are in areas averaging 150 or more frost-free days; plantations B and C average less than 120 frost-free days (fig. 1). Soils at all locations are loams and each plantation is on an upland site.

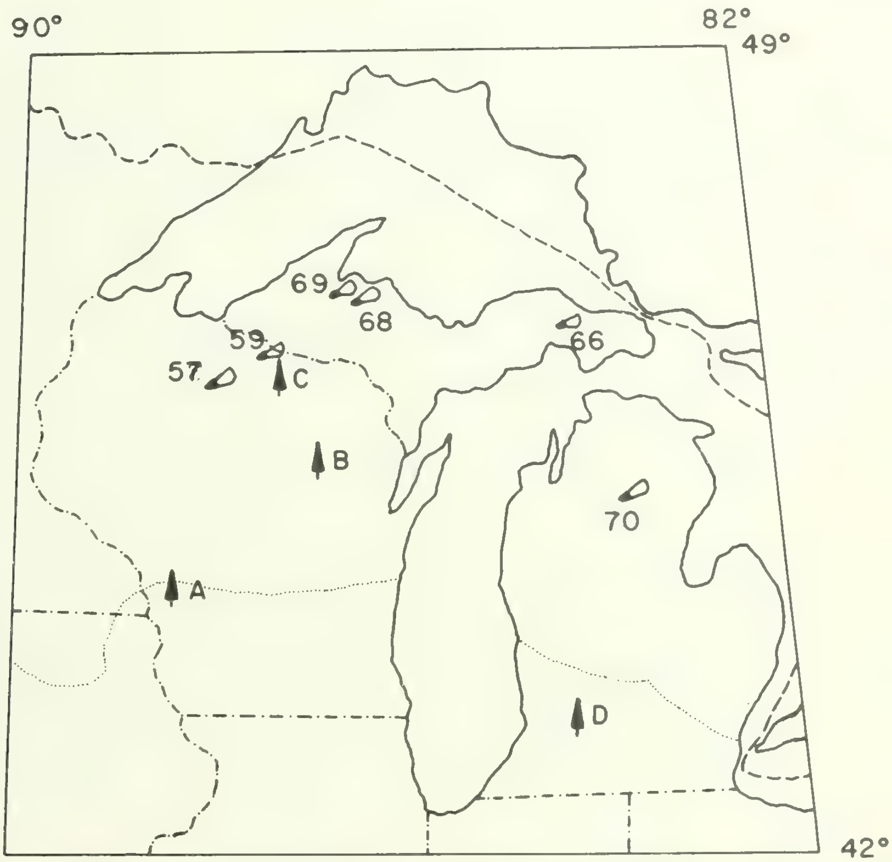

Figure 1.--Map of the study area with numbered provenance locations (⬭) and plantation locations (▲). The southern boundary of the botanical range of balsam fir is indicated by a dotted line.

A call for data was issued to cooperators in 1974 and the most comprehensive data were standardized and analyzed for this summary of results.

Only a few families are represented in all plantations because numbers of seedlings in several families were small. Analyses of variance were based on randomized complete block designs using data only from families and numbers of blocks that were equally represented. A least-significant-difference was calculated following Waller and Duncan (1969). Components of variance were calculated using a random model.

RESULTS AND DISCUSSION

Means for total height show the superiority of Provenance 70 and the inferiority of Provenance 66 (table 1). The array of heights for this provenance sample from the Lake States is similar to the array from range-wide sampling except that some Quebec provenances had greater vigor and some Saskatchewan provenances had less.

Table 1.--Average performance of six balsam fir provenances for four traits at 11 years from seed (height was measured at plantations B, C, and D; lateral branch number at B and C; flushing score at C and D; and lateral bud number at C)

Provenance	Height	Lateral branches	Lateral buds	Flushing score[1/]
	Feet	Number	Number	
57	3.6	3.5	4.0	2.4
59	3.7	3.4	3.7	2.6
66	2.9	2.2	3.1	3.0
68	3.3	3.2	3.8	2.4
69	3.5	3.3	3.8	2.2
70	4.4	4.8	5.1	1.8
Least Significant Difference .05	0.2	0.4	0.2	0.5

1/ Scores range from 1 for least shoot growth initiation to 4 for most shoot growth initiation.

The number of lateral branches in the top whorl was chosen as a variable trait of some interest to Christmas tree growers. Although shearing can increase the density of crowns with few lateral branches, three or less laterals probably would reduce the quality of most Christmas trees. The range of variation again was similar to results from range-wide studies and Provenance 70 was the best.

The number of lateral buds in the top whorl also was variable. The average number of lateral buds is not directly comparable with average number of lateral branches because two plantations are represented in the former array and one in the latter. In plantation C, where both branches and buds were counted, an average of 0.4 bud per tree failed to develop in 1974.

Flushing scores for provenances showed a range of variation similar to that found for other traits. Ranking of provenance means was consistent in both plantations as well as in range-wide provenance data from nursery (Lester 1970) and field plantings. Flushing in Provenance 70 has been observed to be up to 10 days later than in most other provenances and frost damage has been rare. Conversely, Provenance 66 has been heavily frost-damaged in several years, presumably as the result of early flushing. In northeastern Wisconsin, a delay in flushing from May 5 to May 20 would reduce the probability of exposure to freezing temperatures by a factor of four.

When the four traits are viewed in aggregate, the provenances separate consistently into three groups. Provenance 70 is the most vigorous, forms the most lateral branches, and flushes latest. Provenance 66 is the converse of 70 and the other four provenances are intermediate to various degrees. These results raise the question whether differences in height and branching are a consequence of inherently different vigor or of the relation of early spring frost damage to variation in time of flushing. All plantations were damaged by frost in 1 or more years. Although joint effects of variation in vigor and in frost damage cannot be separated in these studies, patterns of shoot growth illustrated by periodic measurements in the nursery (Lester 1970) indicate that both inherent vigor and phenology of bud development are important in determining total height.

The effect of unseasonably low temperature on different stages of bud development needs further study. The loss of potential branches occurs at various stages from before exposure of new leaves to intermediate phases of branch elongation. Loss during early stages of branch elongation seems to be a direct response of succulent tissues to freezing and yet visible damage after frost often occurs only on some of the shoots that have elongated to the point of exposing most of their needles.

Among families within provenances, the range of variation for each trait was between 30 and 40 percent of the provenance mean. Families from Provenance 68 were the most variable for height (55 percent), number of buds (47 percent), and flushing score (54 percent). Families from Provenance 70 were least variable for height (21 percent) but highly variable for flushing score (48 percent).

Both provenance and family effects were almost always highly significant (table 2). Interactions were generally negligible and were relegated to the error term.

Table 2.--Summary of analyses of variance for height, number of lateral branches and buds in the top whorl, and flushing score for provenances and families of balsam fir

Source of variation	Plantation A				Plantation B			
	Height		Number of branches		Height		Number of branches	
	d.f.	F level	d.f.	F level	d.f.	F level	d.f.	F level
Blocks	8		5		8		6	
Provenances	2	**1/	2		5	**	5	**
Families/provenance	9	**	9	**	36	**	36	**
Error	87		55		326		240	

Source of variation	Plantation C				
	Height		Number of branches	Number of buds	Flushing score
	d.f.	F level	F level	F level	F level
Blocks	9	**	**	**	
Provenances	5	**	**	**	**
Families/provenance	30	**	**	**	**
Error	315				
	Plantation D				
Blocks	2				
Provenances	5	**			**
Families/provenance	30	*			*
Error	68				

1/ Means differ at a probability of 99 percent (**) or 95 percent (*).

Components of variance (table 3) show that variation attributable to provenances was three to four times greater than that attributable to families within provenance. Provenance selection is thus the indicated first step for improving balsam fir in the Lake States.

Table 3.--Summary of analysis of variance with variance components for height (plantations B, C, and D) and number of lateral branches in the top whorl (plantations B and C) for balsam fir provenances and families

Source of variation	Height			Lateral Branches		
	d.f.	Significance level	Variance component	d.f.	Significance level	Variance component
Locations 1/	2	** 2/	27 3/	1	**	25
Provenances	5	**	20	5	**	23
Families/Provenance	18	**	7	18	**	6
Error	190		46	311		46

1/ Location effects may be confounded with effects attributable to stock age at time of planting due to different years of planting.

2/ Means differ at a probability of 99 percent (**) or 95 percent (*).

3/ Percentage of total variance.

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EASTERN WHITE PINE SEED SOURCE VARIATION
IN THE NORTHEASTERN UNITED STATES: 16-YEAR RESULTS

Maurice E. Demeritt, Jr., and Harry C. Kettlewood[1]

ABSTRACT.--Twelve eastern white pine (*Pinus strobus* L.) provenance plantations in the northeastern United States were measured for 16-year height and diameter. Differences in height between northern and southern sources have diminished since the 10-year measurements. In general, the 16-year diameter measurements follow the same trends as do the 16-year-height measurements. Recommendations for selection and movement of seed from one region to another are discussed.

In 1955 the USDA Forest Service began a range-wide seed-source study of eastern white pine (*Pinus strobus* L.) to find the geographic variation in selected traits and to make recommendations for the movement of seed over the species' range. Sixteen-year results for total height and diameter measurements of 29 seed sources in 12 field plantings at 10 locations in the northeastern United States are reported here.

METHODS AND MATERIALS

Cones from 10 trees chosen at random in good stands of natural origin were collected. Cones, seeds, and resulting seedlings were kept separate by parent tree within source through the nursery phase of the study in the Northeast. Seedlings within sources were bulked when lifted from the nursery beds and then were randomly selected for field plots. The location of field plantings and seed-source origins are listed in tables 1 and 2. All seed sources were not represented in every field planting.

Plantations 7 through 11 were established in 1959 with 2-0 seedlings grown in the Maryland State Forest Nursery. Plantations 1 through 4 were established in 1960 with 3-0 seedlings grown in the New Jersey and New York State Forest Nurseries. A detailed description of plantation sites, site preparation, and care has been previously reported (Garrett *et al.* 1973)

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Table 1.--Location and design of plantations

Plantation No. and location		Field design	Latitude	Longitude	Elevation
					(feet)
1	Orono, ME	III	44°53'N	68°39'W	100
2	Alfred, ME	I, II, III	43°32'N	70°40'W	300
3	Essex Junction, VT	III	44°28'N	73°09'W	327
4	Paul Smiths, NY	I	44°26'N	74°13'W	1,815
6	Warren, PA	I	41°50'N	79°15'W	1,180
7	Standing Stone, PA	III	40°37'N	78°55'W	960
8	Kennett Square, PA	I	39°52'N	75°41'W	400
9	Savage River State Forest, MD	III	39°40'N	79°15'W	2,740
10	Horseshoe Run, WV	I	39°11'N	79°35'W	1,720
11	Rison, MD	II	38°30'N	77°20'W	100

Plantations 7 through 11 were established in 1959 with 2-0 seedlings grown in the Maryland State Forest Nursery. Plantations 1 through 6 were established in 1960 with 3-0 seedlings grown in the New Jersey and New York State Forest Nurseries. A detailed description of plantation sites, site preparation, and care has been previously reported (Garrett *et al.* 1973).

Three field designs, all randomized complete blocks, are represented.

Design I.--One tree from each seed source randomly located in each of 24 blocks at a spacing of 10 by 10 feet.

Design II.--Two-tree-row plots from each seed source randomly located in each of 24 blocks. Seed-source trees were planted at a spacing of 7 feet in rows and 14 feet between seed-source rows. Additional commercial seedlings were planted between seed-source rows to obtain a spacing of 7 by 7 feet.

Design III.--Four-tree-row plots from each seed source randomly located in each of 12 blocks. Seed-source trees were planted at a spacing of 7 feet in rows and 14 feet between seed-source rows. Additional commercial seedlings were planted between seed-source rows to obtain a spacing of 7 by 7 feet.

The additional (nonstudy) trees were removed from all plantations 1 to 3 years before 16-year measurements.

Table 2.--Seed-source locations for white pine provenance study

Seedlot No. and location		Latitude	Longitude	Elevation (feet)
1	Union County, GA	34°46'N	84°03'W	2,450
2	Transylvania County, NC	35°14'N	82°38'W	2,120
3	Greene County, TN	36°00'N	82°48'W	2,250
4	Garrett County, MD	39°39'N	78°45'W	2,460
5	Greenbrier County, WV	38°00'N	80°30'W	2,600
6	Monroe County, PA	41°05'N	75°25'W	1,800
7	Monroe County, PA	41°05'N	75°25'W	740
8	Clearfield County, PA	41°00'N	78°30'W	--
9	Clearfield County, PA	41°00'N	78°30'W	--
10	Ulster County, NY	41°45'N	74°15'W	--
11	Ulster County, NY	41°45'N	74°15'W	--
12	Franklin County, NY	44°25'N	74°15'W	1,600
13	Worcester County, MA	42°30'N	72°15'W	1,275
14	Penobscot County, ME	44°51'N	68°38'W	150
15	Allamakee County, IA	43°15'N	91°30'W	1,000
16	Ashland County, OH	40°45'N	82°15'W	1,000
18	Forest County, WI	45°30'N	88°30'W	1,500
19	Cass County, MN	47°30'N	94°30'W	1,300
20	Lunenburg County, Nova Scotia	44°25'N	64°35'W	150
21	Sunbury County, New Brunswick	46°00'N	66°15'W	200
22	Quebec County, Quebec	47°30'N	72°00'W	550
23	Pontiac County, Quebec	47°30'N	77°00'W	1,000
24	Norfolk County, Ontario	42°40'N	80°27'W	750
25	Algoma District, Ontario	46°10'N	82°37'W	650
27	Carroll County, NH	43°45'N	71°25'W	610
28	Lake County, MN	48°00'N	91°45'W	1,300
29	Houghton County, MI	47°00'N	88°30'W	625
30	Pulaski County, VA	37°00'N	80°50'W	2,400
31	Sauk County, WI	43°30'N	89°30'W	1,000

Total height and diameter were measured on each seed-source tree after the 1972 growing season (16 years from seed), except for the three plantations at Alfred, Maine. The Alfred plantations were measured after the 1973 growing season (17 years old), and the data were corrected to 1972.

Analyses of variance for diameter and total height, using plot means, were calculated for each plantation using a least-squares and maximum-likelihood general-purpose program. The program partitioned the total sum of squares into sum of squares for blocks, seed sources, and residual (Block x Seed Source Interaction plus Error).

At each plantation every seed-source mean for height and diameter was divided by the plantation mean and then multiplied by 100. With this statistic we were able to evaluate seed sources across all plantations (tables 3 and 4). It must be noted, however, that increasing height and diameter create a scale effect so equal relative differences do not imply equal actual differences.

RESULTS AND DISCUSSION

Seed-source differences were significant at the 1-percent probability level for total height and diameter at 16 years from seed at all 12 field plantations. This variability in growth traits among seed sources indicates that particular seed sources can be selected for use in certain geographic areas.

Blocks were significantly different at the 1-percent probability level except in plantations 9 and 10. The use of randomized complete block design was efficient at locations where blocks were significantly different because it removed site variation from seed-source variation, which gave us better information on the performance of the seed sources at those locations.

Height Growth

The relative differences in height growth between northern and southern sources of eastern white pine have diminished since the 10-year measurements were made, although actual differences have increased in all plantations (table 3, Garrett et al. 1973). At 10 years of age, southern sources were clearly superior. This same trend has been observed in the Central States in measurements at 10 and 15 years, although the magnitude of the relative differences is greater in the Central States (Funk et al. 1975).

In the study reported here, the differences between southern and northern sources were no greater in southern plantations with no or little weeviling (plantations 8 through 11) than they were in northerly plantations with previously good growth but heavy weeviling (plantations 6 and 7). Therefore, the decrease in superiority of southern sources in the Northeast compared to the Central States does not seem to be the result of the white pine weevil (*Pissodes strobi* Peck.) attacking and killing leaders of southern source trees.

Nor is the decreased superiority of southern sources caused by growing-space limitations. The southern-source trees did not grow any taller in Design I plantations at a 10 by 10 foot spacing than they did in Design II and III plantations at a 7 by 7 foot spacing before thinning. It may be that southern-source trees in the Northeast are good early growers, but lose their superiority with time. If this is the case, it will be difficult to evaluate seed sources in provenance tests at an early age.

Table 3.--Height at 16 years from seed of white pine seed-source plantations (seed source mean as percentage of plantation mean)

No.	Seed Source and location	Plantation location: Cent. Maine 1 1/	Vt. 3 1/	N.Y. 4 2/	S. Maine 2 2/	S. Maine 2 3/	S. Maine 2 1/	N.W. Pa. 6 2/	Cent. Pa. 7 1/	S.E. Pa. 8 2/	W. Md. 9 1/	W. Va. 10 2/	S. Md. 11 3/
1	Georgia	85	107	88	95	89	97	113	118	113	115	110	114
2	North Carolina	89	99	79	94	94	98	102	114	100	106	105	103
3	Tennessee	89	103	99	99	97	103	118	120	120	122	108	121
30	Virginia	--	92	--	105	--	76	--	86	75	--	92	88
5	West Virginia	94	99	99	99	102	100	105	95	104	105	107	99
4	Maryland	86	97	98	101	97	95	107	110	96	115	98	100
16	Ohio	101	104	106	99	98	106	101	101	100	108	96	94
8	Pennsylvania	93	106	108	99	97	106	--	106	101	92	103	98
9	Pennsylvania	114	102	109	105	106	108	117	113	109	116	115	108
6	Pennsylvania	108	105	106	102	101	107	114	106	106	114	109	99
7	Pennsylvania	104	--	96	100	102	102	--	--	--	--	--	--
10	New York	104	103	108	106	103	106	104	113	101	107	102	99
11	New York	118	110	117	107	106	106	105	117	111	112	108	100
13	Massachusetts	110	106	105	108	104	109	109	100	106	104	108	102
24	Ontario	108	110	95	111	108	107	89	115	106	107	112	108
15	Iowa	95	94	99	91	93	94	92	91	95	--	98	95
31	Wisconsin	--	--	--	--	--	--	--	91	105	98	103	106
27	New Hampshire	101	105	--	103	99	108	--	105	107	--	--	109
12	New York	103	103	110	103	102	105	108	101	103	102	99	104
20	Nova Scotia	106	104	95	104	108	103	89	98	100	98	100	101
14	Maine	105	106	111	103	97	101	90	94	93	93	93	95
18	Wisconsin	101	93	103	95	99	97	106	83	95	--	--	92
25	Ontario	108	85	--	93	--	102	89	95	103	89	100	97
21	New Brunswick	99	98	88	97	97	91	100	93	81	84	87	97
29	Michigan	--	--	88	96	93	85	--	85	98	86	93	86
19	Minnesota	99	97	92	97	99	102	103	89	100	100	98	97
22	Quebec	80	86	89	97	84	75	68	74	85	66	78	87
23	Quebec	87	90	--	84	--	95	35	82	86	84	90	81
28	Minnesota	97	94	--	--	--	98	--	91	87	88	92	94
	[illegible]	15.7	17.3	14.3	16.8	18.7	19.5	22.2	17.3	20.5	16.1	29.1	26.7

In general, seedlings of southern sources (Georgia, North Carolina, and Tennessee) grew as well as or better than those from most northerly sources in plantations as far north as central Pennsylvania. Garrett et al. (1973) found this same trend for 10-year-height measurements. Faster height growth has also been reported for trees from southern Appalachian sources in the Central States (Funk 1971, Lee 1974, Funk et al. 1975). Sluder and Dorman (1971) found that southern-source trees grew better in North Carolina, Georgia, and Virginia than did those from more northerly sources at 10 years of age. Southern Appalachian sources were no taller than slightly more northerly sources, but were taller than far northern sources at 7 years of age when grown in Ontario (Fowler and Heimburger 1969). Thor (1975) found in a number of tests in Tennessee with a different collection of seed sources that local and southerly sources grew better than more northerly sources from Virginia, West Virginia, and Pennsylvania.

Sources 6 and 9 from Pennsylvania, 11 from New York, 13 from Massachusetts, and 24 from Ontario grew well in all plantations, even when they were moved some distance south from their origin. Garrett et al. (1973) found this same trend for these five sources for 10-year-height measurements.

Responses varied between sources from the same county within a State. Sources 6 and 9 from Pennsylvania grew better at most locations than sources 7 and 8 from the same counties. Also, source 11 from New York grew better at all locations than source 10 from the same county. This indicates that only proven sources from a geographic region should be selected and collected.

The Central States plantations do not have as many of the sources as the Northeast plantations, thus it is difficult to make good comparisons between regions. Some good sources from the Northeast did well in Lower Michigan at age 15 (Lee 1974) and in the Central States (Funk 1971, Funk et al. 1975). Fowler and Heimburger (1969) recommend sources from the Pennsylvania area for planting in Ontario, based on 7-year-height data.

Diameter Growth

At 16 years of age the range of differences in seed-source diameters is equal to or greater than the range of differences in height at each plantation, except the northwestern Pennsylvania plantation (table 4). In general, the ranking of seed sources is the same whether height or diameter is used as the measurement. Wright (1970) found a strong relation between height and diameter at 11 years for 15 sources in southern Michigan.

Table 4.--Diameter at 16 years from seed of white pine seed-source plantations (seed source mean as percentage of plantation mean)

No.	Seed source and location	Cent. Maine 1[1/]	Vt. 3[1/]	N. Y. 4[2/]	S. Maine 2[2/]	S. Maine 2[3/]	S. Maine 2[1/]	N.W. Pa. 6[2/]	Cent. Pa. 7[1/]	S.E. Pa. 8[2/]	W. Md. 9[1/]	W. Va. 10[2/]	S. Md. 11[3/]
1	Georgia	79	112	93	98	91	100	128	136	131	117	132	142
2	North Carolina	79	104	62	92	96	102	97	125	106	100	124	116
3	Tennessee	79	104	92	97	97	108	127	125	131	121	123	143
30	Virginia	--	85	--	105	--	73	--	96	64	--	88	86
5	West Virginia	85	90	96	94	97	99	102	94	103	107	106	104
4	Maryland	79	82	93	97	97	96	109	106	95	120	99	97
16	Ohio	101	109	102	101	101	113	94	98	94	105	97	90
8	Pennsylvania	95	112	108	102	96	104	--	107	99	87	109	101
9	Pennsylvania	115	103	103	109	106	113	124	118	112	120	128	111
6	Pennsylvania	117	112	105	102	104	111	119	114	113	116	120	102
7	Pennsylvania	116	--	91	104	101	97	--	--	--	--	--	--
10	New York	103	109	128	113	105	112	100	114	110	107	103	105
11	New York	120	110	123	109	109	106	102	118	117	116	112	103
13	Massachusetts	115	112	98	113	111	116	112	104	114	103	125	105
24	Ontario	100	115	100	108	109	105	83	122	107	103	119	117
15	Iowa	97	97	101	93	102	92	87	89	100	--	96	87
31	Wisconsin	--	--	--	--	--	--	--	91	107	98	104	108
27	New Hampshire	104	111	--	103	101	109	--	108	111	--	--	130
12	New York	107	105	106	107	103	106	113	93	107	108	98	105
20	Nova Scotia	110	109	96	107	110	100	81	92	92	90	85	92
14	Maine	111	102	109	106	98	101	84	94	88	95	86	88
18	Wisconsin	102	91	113	90	97	100	99	86	87	--	—	77
25	Ontario	113	88	--	94	--	101	84	91	101	96	88	93
21	New Brunswick	104	92	93	95	93	89	94	90	72	85	75	93
29	Michigan	--	--	84	97	90	84	--	80	97	84	81	74
19	Minnesota	98	95	90	99	102	99	95	84	102	97	93	84
22	Quebec	80	81	98	96	76	78	62	71	75	70	65	76
23	Quebec	80	82	--	74	--	87	55	69	74	74	78	69
28	Minnesota	100	92	--	--	--	95	--	79	79	72	79	81
	Plantation mean (in inches)	2.70	3.67	3.04	4.21	4.32	4.54	4.64	3.25	4.53	2.98	5.89	4.14

1/ Design III. 2/ Design I. 3/ Design II.

CONCLUSIONS

1. The Georgia source (1) and the Tennessee source (3) should be selected for planting as far north as central Pennsylvania because of their above-average growth in height and diameter.

2. Pennsylvania sources 6 and 9, New York source 11, Massachusetts source 13, and Ontario source 24 should be selected for planting in the United States north and east of central Pennsylvania.

3. Only proven sources within seed-collection zones should be selected for seedling production.

4. Additional fast-growing sources from the regions outlined in conclusions 1 and 2 may be identified and added through further testing of sources.

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STAND, FAMILY, AND SITE EFFECTS IN UPPER OTTAWA VALLEY WHITE SPRUCE[1]

N. K. Dhir[2]

ABSTRACT.--Forty-nine open-pollinated white spruce progenies from eight Upper Ottawa Valley white spruce stands were tested at three sites located within 10 miles of each other. Statistical analyses were limited to 42 families--6 from each of 7 of the stands. Performance was site dependent with nearly a two-fold difference between the best and the poorest. Differences due to stands were not important. The best family was 28 percent taller than the family mean height, but performance was not consistent from site to site in spite of a nonsignificant family-site interaction term. This probably was due to limitations imposed by the statistical design. Heritability estimates for heights were h^2_i (individual tree heritability) = 0.10; h^2_f (family heritability) = 0.39. Genetic gain in 10 year height through one cycle of simple mass selection was estimated to be 8.6 percent; establishing a clonal orchard with the best trees (4 percent selection intensity) from the best families (10 percent selection intensity) in the test boosts the estimated gain to 11 percent. The genetic parameters determined in this study are compared with previously published data.

White spruce (Picea glauca (Moench) Voss) provenances, have been shown to differ widely in growth and survival in field tests covering a broad spectrum of test sites in Canada and the United States (Nienstaedt 1969, Teich 1973). Among the provenances tested, the Beachburg source from the Upper Ottawa Valley performed consistently well in all field tests and showed the best height growth in most tests. These findings generated interest in the Upper Ottawa Valley white spruce populations and more intensive studies of these populations were initiated by the Petawawa Forest Experiment Station (P.F.E.S.).

The objective of the study reported here was to evaluate the significance of variation among and within white spruce stands of the

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Upper Ottawa Valley. Ten-year height growth and survival (6 years after planting) were studied at three test sites. Heritability of height growth was determined and expected genetic improvement in this trait through selection and breeding examined.

MATERIAL AND METHODS

Open-pollinated seeds were collected from 4 to seven trees in eight stands. A total of 49 seedlots (open-pollinated families) was obtained.

Seedlings of the 49 families were raised in the P.F.E.S. nursery and outplanted as 2-2 stock in spring 1969 at 3 sites identified as D-1, D-2, and D-3. The test sites were located within a distance of 10 miles of each other in Head Township, Renfrew County, but varied markedly in their productivity and previous vegetation (fig. 1). Site D-1 was a cutover hardwood stand where young unmerchantable trees remained in the overstory after planting. Its soil was stony with a well developed humus layer. Sites D-2 and D-3 were abandoned farms with a heavy sod overlying a loamy sand.

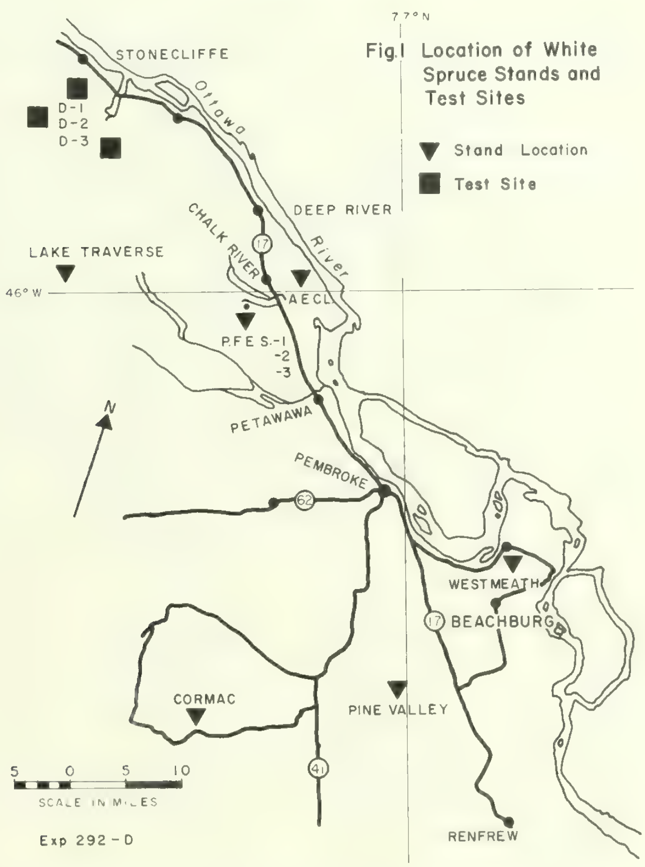

Figure 1.--Location of white spruce stands and test sites.

Planting was done at 1.2 by 1.2 m spacing. Scalping removed competing vegetation within about 20 cm of the planted trees. The experimental design consisted of two replications at each site. Twenty-five tree plots were used at sites D-2 and D-3, but at Site D-1, where lesser survival was anticipated because of stony soil, 40 tree plots were used.

The plantations were generally healthy and showed no serious damage by any pest. The plantation on site D-3, however, had suffered moderate frost damage in early years but appeared to have recovered. Ground competition was considered to be an integral part of the test environment and no attempt was made to control this after the field trials were successfully established.

STATISTICAL ANALYSIS

The data were summarized by standard statistical methods. Standard errors of site and stand means were calculated from the error mean sum of squares of the appropriate analysis of variance (Steel and Torrie 1960).

Analysis of variance for data combined from all the sites was done by using a balanced set of 42 families (6 families each from 7 stands). The analysis of variance format and expectation of the mean sums of squares, assuming a completely random model, are given in table 1. The variance components and their standard errors were determined using procedures described by Hanson (1955). All tests of statistical significance were made at the 5 percent probability level.

Table 1.--Analysis of variance format and expectation of the mean sums of squares

Source of variation	d.f.	E(M.S.S.)[1]
Sites	$\ell-1$	$\frac{\sigma_w^2}{k} + \sigma_e^2 + sf\sigma_{R/L}^2 + rsf\sigma_L^2$
Reps/sites	$\ell(f-1)$	$\frac{\sigma_w^2}{k} + \sigma_e^2 + sf\sigma_{R/L}^2$
Stands	$s-1$	$\frac{\sigma_w^2}{k} + \sigma_e^2 + \ell r\sigma_{F/S}^2 + \ell rf\sigma_S^2$
Families/stands	$s(f-1)$	$\frac{\sigma_w^2}{k} + \sigma_e^2 + \ell r\sigma_{F/S}^2$
Pooled error[2]	$(\ell rsf-sf-\ell r+1)$	$\frac{\sigma_w^2}{k} + \sigma_e^2$
Within plots	$\sum_{i=1}^{\ell rsf}(n_i-1)$	σ_w^2

1 ℓ = No. of sites, r = No. of reps. in each site, s = No. of stands, f = No. of families per stand, n = No. of plants per plot, k = harmonic mean of number of plants per plot.

2 Contains sources of variation due to families x sites and families x reps/sites.

RESULTS

The performance of white spruce families was greatly influenced by test sites (table 2). Mean height on the best site (D-1) was nearly twice as much as on the poorest site (D-3). Site D-1 was characterized by a more favorable moisture regime, lack of severe grass competition, and protection from severe frosts. Poor survival on site D-1 was attributed to difficulty in planting among the stones and stumps on this site.

Table 2.--Mean height and survival of the families at three sites

Site	Height (cm) mean ± s.e.	Survival (percent) mean ± s.e.
D-1	151.1 ± 2.2	79.5 ± 1.2
D-2	120.3 ± 1.6	91.8 ± 0.9
D-3	77.3 ± 1.3	93.7 ± 1.0
All sites	116.2 ± 1.0	88.3 ± 0.6

Mean height of the stands ranged from 110.1 cm to 123.6 cm and mean survival from 82.9 percent to 91.2 percent (table 3). Westmeath showed the best performance among the eight stands studied. Its height growth and survival were respectively 6 percent and 3 percent better than the average (table 4). However, its superiority was not consistent on all sites, e.g., on site D-2 Lake Traverse showed the best height and P.F.E.S. -2 showed the best survival.

Table 3.--Mean performance of white spruce stand collections

Stand origin	Families	Height (mean ± s.e.)	Survival (mean ± s.e.)
	No.	cm	Percent
Westmeath	7	123.6 ± 2.7	91.2 ± 1.6
P.F.E.S. -3	6	118.9 ± 2.9	90.3 ± 1.7
Lake Traverse	4	117.1 ± 3.5	87.1 ± 2.1
Pine Valley	7	115.9 ± 2.7	89.6 ± 1.6
A.E.C.L. Reserve	7	115.4 ± 2.7	88.3 ± 1.6
P.F.E.S. -2	6	113.7 ± 2.9	88.5 ± 1.7
Cormac	6	113.4 ± 2.9	82.9 ± 1.7
P.F.E.S. -1	6	110.1 ± 2.9	87.4 ± 1.7

Table 4.--Performance of the best stand and family at each site as percent of the site mean

	Height			Survival			D-1,D-2,D-3 combined	
	D-1	D-2	D-3	D-1	D-2	D-3	Height	Survival
Stand	106	110	112	105	106	105	106	103
Family	128	138	132	118	109	107	128	108

Individual families varied more in height than they did in survival (table 4). Considering all sites, the tallest family was found to be 29 percent taller than the average. Mean height and survival of the families showed significant correlation for site D-2 (r = 0.54) and D-3 (r = 0.46) but not for site D-1 (r = 0.19).

Performance of individual families was generally inconsistent from site to site and the family ranks fluctuated considerably. This is illustrated by simple correlation coefficients of family means on different sites (table 5); correlations based on family ranks were very similar. Out of the 49 families studied, only 7 showed above average height growth on all test sites.

Table 5.--Simple correlation coefficients of family height and survival means among test sites

		D-2	D-3
D-1	Height	0.11	0.01
	Survival	0.02	0.16
D-2	Height	--	0.31*
	Survival	--	0.29*

* Significant at $p < 0.05$

The error mean squares of the analyses of variance were derived by pooling families x sites and families x replications in sites sums of squares because families-sites interactions were negligible for both height and survival (respective F-ratios 0.95 and 0.90) (table 6). Sites, replications in sites, and families in stands were significant sources contributing to the variability of height growth but percent survival was significantly influenced by sites and reps in sites only (table 6).

Table 6.--Mean squares in the analyses of variance and corresponding variance components and their standard errors

Source of variation	d.f.	M.S.S. Height	M.S.S. Survival	Variance components: Component estimated	Variance components: Height	Variance components: Survival
Sites	2	113,354 1/	5,713 1/	σ_L^2	1281.5±1350.6	60.1±68.3
Reps/sites	3	5,711 1/	668 1/	$\sigma_{R/L}^2$	128.8± 111.0	13.4±13.0
Stands	6	686	273	σ_S^2	5.8± 11.5	4.1± 4.5
Families/stands	35	479 1/	125	$\sigma_{F/S}^2$	35.6± 19.7	4.0± 5.2
Pooled error	205	295	101	σ_e^2 2/	250.3± 29.2	100.7± 8.3
Within plots (k=25.08)	7,609	1,128	--	σ_W^2	1,128.3 18.3	--

1/ Significant at $p<0.05$

2/ For survival, variance component estimated is $\frac{\sigma_W^2}{k} + \sigma_e^2$.

Estimates of narrow sense heritability of tree height for individual plants (h_1^2) and family means (h_2^2) reference units were constructed from the variance components listed in table 6 (Comstock and Robinson 1948, Dudley and Moll 1969). It was assumed that the members of individual families were true half-sibs.

h_1^2 (individual tree heritability) $= \frac{\sigma_A^2}{\sigma_p^2} = \frac{142.4}{1,420.0} = 0.10$

h_2^2 (family heritability)[3] $= \frac{\sigma_{A'}^2}{\sigma_{\bar{p}}^2} = \frac{35.6}{90.6} = 0.39$

3 The correct numerator for computing family heritability can be either $\sigma_{A'}^2$, as used in the case illustrated above, or $2\ \sigma_{A'}^2$ depending upon the type of selection to be practiced (Dudley and Moll 1969).

Where[4]

$$\sigma_A^2 = 4\ \sigma_{F/S}^2 \quad \text{(additive genetic variance of individual trees)}$$

$$\sigma_p^2 = \sigma_w^2 + \sigma_e^2 + \sigma_{F/S}^2 + \sigma_S^2 \quad \text{(phenotypic variance of individual trees)}$$

$$\sigma_{A'}^2 = \sigma_{F/S}^2 \quad \text{(additive genetic variance of half-sib families)}$$

$$\sigma_{\bar{p}}^2 = \frac{\sigma_w^2}{\ell rk} + \frac{\sigma_e^2}{\ell r} + \sigma_{F/S}^2 + \sigma_S^2 \quad \text{(phenotypic variance of half-sib families)}$$

Heritability of survival percentage was not calculated because the effects of families in stands for this trait were not significant. Because stand origin effects were also nonsignificant, it can be assumed that variability in the surviving ability of the families was purely environmental in origin.

DISCUSSION

Genetic differences in 10-year height of local white spruce in the Upper Ottawa Valley were primarily due to mother trees as shown by the performance of their progenies. Differences attributable to stand origin were not important, which suggests a lack of genetic differentiation among local white spruce populations. Similar findings were reported by Yeatman (1975) for early height growth of the Ottawa Valley jack pine progenies. Substantial variation among open-pollinated progenies of white spruce was reported in earlier studies by Holst and Teich (1969) and Jeffers (1969). These workers, however, sampled material from wider geographic areas and tested it at only one location.

Site had a dominating influence on performance of the families but family-site interactions were statistically nonsignificant. Absence of family-site interaction usually implies a good agreement in the ranking of families on different sites, but this was not true for the results of this study. This was largely due to inconsistency in the performance of families among replications on individual sites. It was, therefore, felt that the experimental design used in this study provided a poor control of site heterogeneity. Smaller plots and three or more replications per site would have increased the efficiency of the tests.

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4 See tables 1 and 6 for definition of variance components and subscripts.

The single tree heritability value of 0.10 for 10-year height, reported here, is similar to a value of 0.145 obtained by Yeatman (1975) for 6-year height in the Ottawa Valley jack pine in a similar experimental design and reference environment. Heritability values for 8- and 11-year heights of Ontario white spruce ranged from 0.06 to 0.18 on an individual tree basis and from 0.75 to 0.91 on a family basis, in the studies reported by Holst and Teich (1969). However, the procedure used by these authors for computing heritability differs from the one used in the present study so the results are not comparable.[5]

Heritability values should always be interpreted with caution because such values are applicable only to the defined base population, reference selection unit, and reference test environment (Hanson 1963, Dudley and Moll 1969). Furthermore, heritability estimates obtained from genetic parameters estimated by open-pollinated progeny tests, assuming families to be true half-sibs, are expected to be biased and tend to be inflated (Namkoong 1966, Squillace 1974).

Genetic parameters estimated in this study can be used to derive the expected genetic gain through selection and breeding (Namkoong et al. 1966, Shelbourne 1969). Genetic gain in 10-year height of the Upper Ottawa Valley white spruce through one cycle of simple mass selection was estimated to be 8.6 percent. This is an appreciable gain and particularly noteworthy in view of the poor heritability of this trait reported by this study. Genetic gain resulting from the seed produced in a clonal seed orchard, established with scions collected from the tallest tree in each plot (4 percent selection intensity) of the top five families (10 percent selection intensity), was estimated to be 11 percent.

The heritability of early height found in this study is less than the value of this parameter suggested by white spruce progeny tests in the Lake States (Jeffers 1969, Mohn et al., these proceedings). As pointed out earlier, experimental plantations used by this study suffered several shortcomings and it is likely that field experiments emphasizing better design and more uniform treatment of experimental units will show higher heritability for this trait of local white spruce in the Upper Ottawa Valley.

SUMMARY AND CONCLUSIONS

1. Open-pollinated progenies of the Upper Ottawa Valley white spruce stands (provenances) were studied for early height growth and field survival at three test sites.

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5 Method used by Holst and Teich (1969) in their heritability calculations does not take into account "within plot" variance. This method is appropriate for one-way classification experiments but not for multi-way classification experiments. Also for family heritability calculations they used $2\,\sigma_A^{2}$ in the numerator. The formulae used by Holst and Teich (1969), give the following values with my data: single tree heritability = 0.06; family heritability = 0.63.

2. The stands showed similar performance indicating lack of genetic differentiation among them for the traits studied. It appears that the superior white spruce sources of Beachburg and Douglas identified in earlier provenance tests are part of a larger population that extends beyond the original collection area of these sources. Further studies with more intensive sampling of stands and better field design are needed to delineate the boundaries of this population complex.

3. Site had a dominating influence on progeny performance, which was very inconsistent from site to site.

4. Substantial variation was found for height growth among families but their ability to survive in the field was primarily determined by the site factors.

5. Heritability of individual plant height was low (0.10) but appreciable genetic gain (8.6 percent) was expected to result from one cycle of simple mass selection at 1 percent selection intensity. Overall benefits resulting from white spruce breeding in the Upper Ottawa Valley, using multistage and multitrait selection procedures, can be expected to be larger than the 8.6 percent gain reported for simple mass selection.

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A WHITE SPRUCE PROGENY TEST--SEEDLING SEED ORCHARD: 12TH YEAR PROGRESS REPORT[1]

C. A. Mohn, D. E. Riemenschneider, W. Cromell, and L. C. Peterson[2]

ABSTRACT-- Two hundred thirty-nine open-pollinated progenies of white spruce were established in a combination progeny test-seedling seed orchard near Grand Rapids, Minnesota. Characteristics evaluated included, total heights at 2-0 and 2-2 in the nursery and 9 and 12 years from seed (in the field); field survival 9 years from seed was included. Survival was just over 77 percent. Family mean heights were from 60 to 167 percent of the nursery test mean at 2-0 and decreased in variation to from 52 to 125 percent of the plantation mean at age 12. Narrow sense heritabilities (computed as four times the interclass correlation) were 0.27 at age 9 and 0.35 at age 12 and are comparable to earlier results with white spruce in Wisconsin. They exceed Canadian results probably because Canadian material represented a more narrow geographic base. Data suggest a possible relation between growth rates and climatic seed collection zones. Pending further study, nurserymen should not collect seed in the extreme climatic zones in northeastern Minnesota. Plans for conversion of the test to a seed orchard are described. Possible genetic gains of from 15 to 20 percent are predicted on the basis of present genetic parameters.

In 1962 a cooperative improvement project for white spruce (*Picea glauca* (Moench) Voss) was initiated by Blandin Paper Company of Grand Rapids, Minnesota, and the College of Forestry, University of Minnesota. Objectives included the establishment of a small commercial seed orchard to produce improved materials for use in a limited area of north-central

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Minnesota, the development of information concerning genetic variation in the species, and the identification of materials for use in future breeding work.

We decided to run a combination one-parent progeny test and seedling-seed orchard similar to that described by Wright and Bull (1963) for red pine in Michigan. Both the theoretical and applied aspects of such an approach are controversial. However, the choice was dictated by the objectives of the cooperators, the limited physical and human resources available, and our knowledge of white spruce genetics in the early 1960's. This report reviews the establishment of the project, presents a preliminary analysis of data collected through age 12, and outlines plans for future developments.

MATERIALS AND METHODS

Seed Collection

All seeds were collected in 1962. The goal was 200 to 250 individual tree collections from the range of white spruce in Minnesota. To meet this goal, assistance was requested from foresters with the Minnesota Department of Natural Resources and other organizations.

Collectors were instructed to obtain 25 to 30 cones per selected tree, package single-tree collections separately, and mail the cones to a central point along with a legal description of the mother tree's location. Selection criteria for mother trees were not stringent: cooperators were to confine their selections to wild stands, avoid isolated specimens, and choose trees "above average in health and vigor when compared to trees of the same age in the immediate area."

The response by Minnesota foresters was outstanding and 281 usable single-tree collections were assembled. The collections represented the efforts of at least 35 individuals employed by several organizations.

Nursery Phase

Cleaned and dewinged seeds were sown in October of 1962 in the Blandin Nursery near Grand Rapids, Minnesota. The sowing was made in 3 blocks; each block contained 1 plot of each of the 281 seed lots. A plot was a 4-foot row across the nursery beds containing 110 to 150 seeds. Spacing of 6 inches between rows was maintained by using planting boards.

The sowing produced 249 open-pollinated progenies in each of which there were 20 or more healthy seedlings. The seedlings were transplanted in May of 1965 into a randomized complete block design with four replications.

Row plots of 12 trees each were used at a spacing of 4 by 6 inches. Low numbers of seedlings resulted in 33 of the families being transplanted to only 2 or 3 of the 4 plots.

In April of 1967 the 2-2 stock was labeled and lifted. At the conclusion of the nursery phase the original 281 seed lots had yielded 239 open-pollinated progenies with adequate numbers of plantable seedlings (fig. 1).

Outplanting

Seedlings were hand planted in May of 1967 near Grand Rapids, Minnesota, on a gently rolling, old-field site with a sandy-loam soil. Before planting the site was plowed, disked, and divided into 30 contiguous 70 by 80 foot blocks. Spacing of 5 by 5 feet gave 240 positions per block and 1 seedling from each of the 239 families was randomly assigned to each position. The 240th position was filled with surplus seedlings from progenies with more than 30 seedlings as were voids caused by families having less than 30 seedlings. This resulted in the number of trees in a progeny varying from 15 to 38.

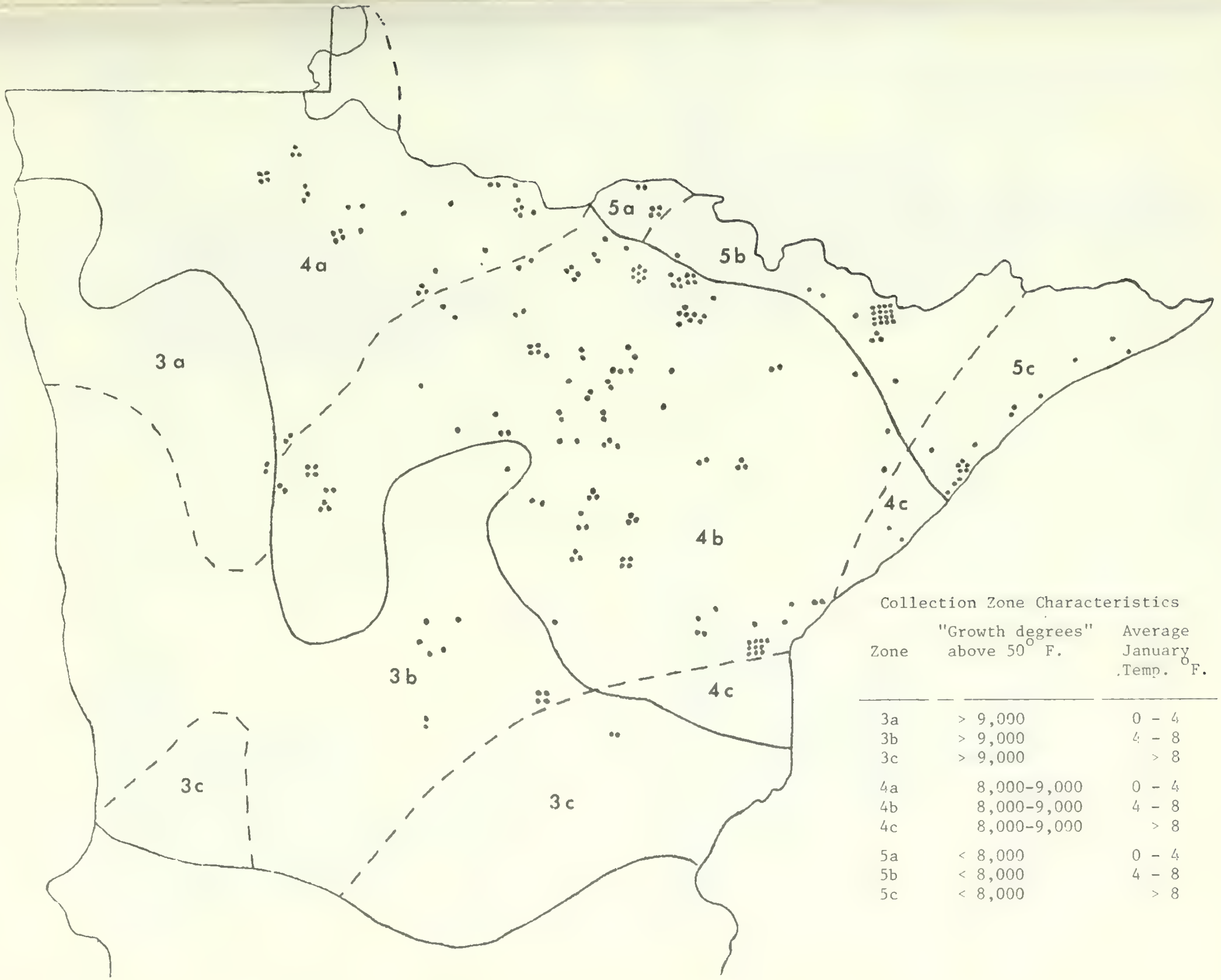
Post planting care include replacing 587 dead plants in 1968, treating an area around each plant with an herbicide in 1968, and spraying with an insecticide to control yellow-headed spruce sawfly each year.

MEASUREMENT AND ANALYSIS

Nursery measurements included the determination of plot mean heights for 2-0 seedlings in 1965 and the 2-2 transplants in 1967 to the nearest centimeter. Mean family heights were computed using these data and compared by analysis of variance, assuming a randomized complete-block design.

Field heights were measured after five and eight growing seasons in the field (in 1971 and 1974). Data from these measurements were examined on the basis of a completely random design because of the large number of missing plots.

Narrow-sense heritabilities for individual differences were calculated as four times the interclass correlation (Falconer 1960, Kung 1972). Further analysis of 12th year height data included computing the means and variances for families from six collection zones. The zones, modified from Rudolf (1956), were defined by average January temperature and the annual sums of normal average daily temperatures per year above 50°F (fig. 1).



Collection Zone Characteristics

Zone	"Growth degrees" above 50^{o} F.	Average January Temp. ^{o}F.
3a	> 9,000	0 - 4
3b	> 9,000	4 - 8
3c	> 9,000	> 8
4a	8,000-9,000	0 - 4
4b	8,000-9,000	4 - 8
4c	8,000-9,000	> 8
5a	< 8,000	0 - 4
5b	< 8,000	4 - 8
5c	< 8,000	> 8

Figure 1.--Location of mother trees and seed collection zones for white spruce seedling seed orchard-progeny test.

Simple correlation coefficients among family means for height at the four measurement ages and survival in 1971 (age 9) were calculated.

Significance levels for all tests were set at 0.05.

RESULTS

Field Survival

All the field mortality occurred during the first 5 years after planting. By 1974, eight growing seasons after field planting, survival was just over 77 percent. On a family basis, survival ranged from 39 to 100 percent. The average family had 23.5 living plants and only 11 of the 239 families were represented by less than 15 trees. Mortality was strongly related to location in the planting with losses in the 30 blocks ranging from less than 1 percent to 55 percent.

Height Growth

Growth in the nursery and during the first 5 years in the field was slow (table 1). However, from 1972 to 1974 (10th-12th years) it averaged 28 cm per year. Much variation in individual tree height was shown by the field data. The standard deviations of individual tree heights were equal to 36 percent and 34 percent of the plantation mean in the 9th and 12th years, respectively.

Table 1.--Summary of nursery and field height measurements

Year	Years materials in: Seed-bed	Transplant bed	Field	Families	Test mean	Standard deviation (indiv.tree)	Range of family me: Actual	Test m
				(No.)	(cm)	(cm)	(cm)	(perce
1964	2	--	--	237[1/]	8.8	--	5.3-14.7	60-16
1966	2	2	--	237[1/]	17.2	--	8.3-24.8	48-14
1971	2	2	5	239	101	36	57-129	56-12
1974	2	2	8	239	184	62	96-230	52-12

1/ Two families omitted from nursery data because of missing plots.

Differences among open-pollinated families were significant for all height measurements (fig. 2). The range of family means was largest for the 2-0 measurements which ran from 60 to 167 percent of the plantation mean. Although the range of family means decreased over time (table 1), at age 12 it still ranged from 52 to 125 percent of the plantation mean.

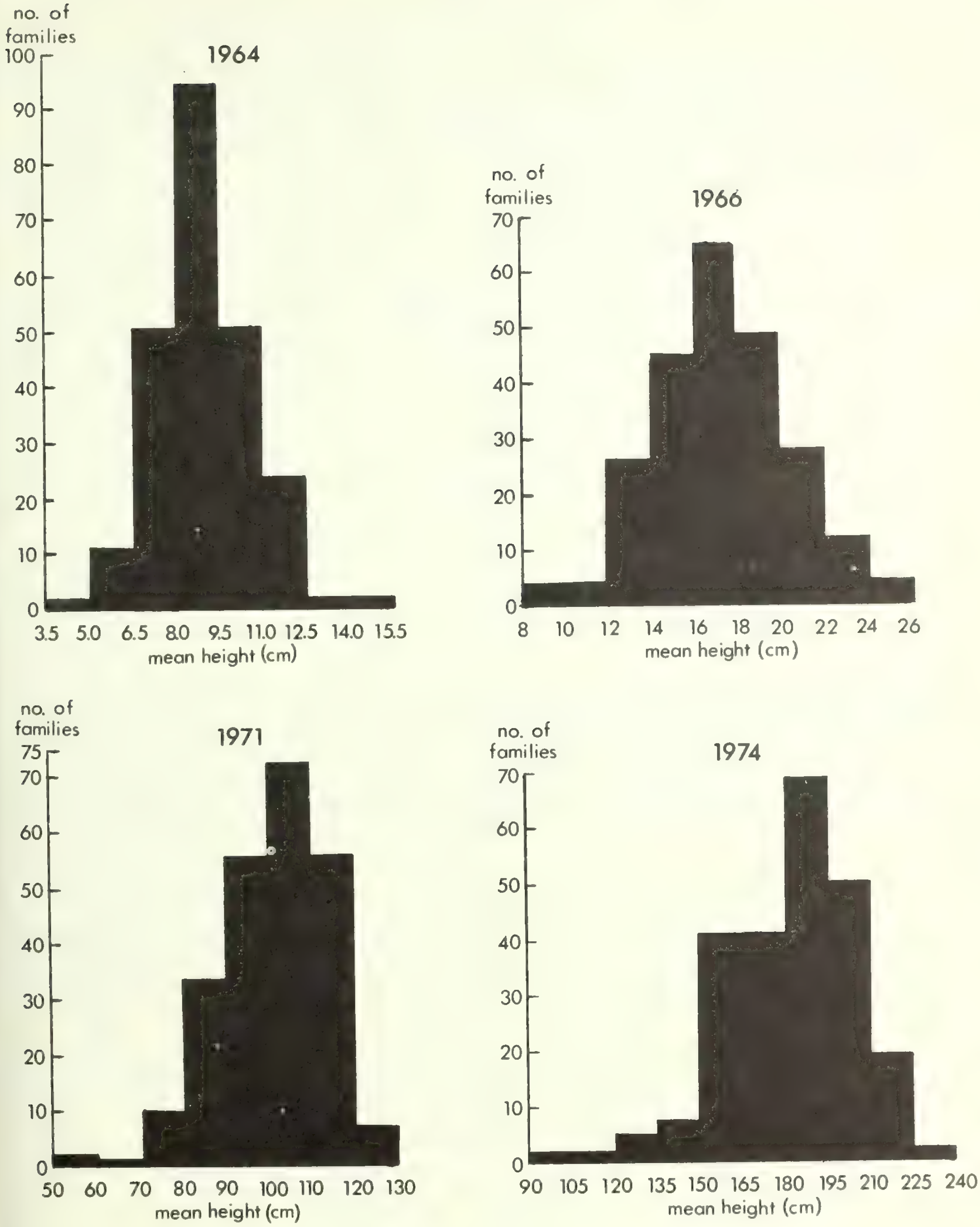


Figure 2.--Distributions of white spruce open-pollinated family means for height.

Narrow-sense heritabilities (individual tree basis) were 0.27 at age 9 and 0.35 at age 12.

The mean 12th-year heights for families from the six collection zones in which six or more individual trees were sampled are given in fig. 1, tabl Bartlett's test indicated that the variances for the zones exhibited heterogeneity and the data were not subjected to further analysis (Steel and Torrie 1960).

Table 2.--Mean 12th-year heights for families in six collection zones

Seed collection zone 1/	Families in sample	Mean height of families	Family variance	Standard error of mean
	(No.)	(cm)		
3b	12	193.2	8.58	4.57
4a	34	188.4	7.24	2.44
4b	138	183.8	15.36	1.83
5a	6	179.2	17.69	9.45
5b	24	177.4	12.06	3.96
5c	16	152.4	25.59	6.71

1/ Collection zone shown in figure 1.

The simple correlation coefficients of family mean heights for the four measurement dates and mean 9th year survival are given in table 3. All correlations between these variables were statistically significant.

Table 3.--Simple correlation coefficients (r) 1/ for heights and 1971 survival

	2-0 height	2-2 height	9th year height	12th year height
1971 survival	.29	.48	.40	.48
2-0 height		.54	.44	.43
2-2 height			.58	.60
9th year height				.90

1/ r values are significant at the 5 percent level if they exceed 0.

DISCUSSION

Heritabilities from similar tests with white spruce were converted to a common basis using the procedures outlined by Kung (1972). Jeffers' (1969) data for the height of 28 open-pollinated families at age 4 gave a value close to those obtained in this study (0.34 vs. 0.27 and 0.35). In contrast, heritabilities established from 8th or 11th year data from 4 Ontario tests with 8 to 18 open-pollinated progenies ranged from 0.03 to 0.09 (Holst and Teich 1969).

It should be noted that the Minnesota and Wisconsin test materials came from a wide geographic area, but three of the four Ontario tests sampled a very limited area. The data summarized by table 2, although not evaluated statistically, suggest differences among materials from the several seed collection zones. A trend toward greater heights with increasing annual sums of normal average daily temperatures of 50°F or above and with lower average January temperatures may exist. Given these results, a reduction in variation would be anticipated when working with geographically restricted populations.

The possible relation of growth rates to collection zones suggested by the data also has implications for seed collection in Minnesota. Pending further study, nurserymen would be advised to avoid the northeastern region of the State; i.e., zones 5a, 5b, and particularly zone 5c (fig. 1).

Correlations between nursery and field height, although positive and statistically significant are only moderately high (table 3). Nursery-field correlations do not suggest that nursery data can form the primary base for selection. However, they are strong enough to indicate that culling in the nursery could improve cost/gain ratios in white spruce improvement programs.

Predictions of genetic gain based on the results of these data are encouraging. Given the heritabilities and magnitude of phenotypic variation observed for 9th and 12th year heights, conversion of the progeny test to a seed orchard by removing 90 percent of the trees would give an expected genetic gain in height growth of 15 to 20 percent.

Such predictions should be viewed with caution, however. The height data are for a maximum age of 12, which is far from rotation age. At least some culling of the materials must be done on the basis of early growth and, unless juvenile-mature correlations are high, predicted gains will be reduced. However, there is evidence of juvenile growth superiority of provenances persisting 29 years after field planting (Nienstaedt 1969), and the observed 9th-12th year correlation coefficient of 0.9 is encouraging.

It is also important to realize that testing was limited to a single site. Estimates of additive genetic variance and consequent predicted gains are biased upward by the failure to estimate the genotype-environment interaction component. The impact of this bias is unknown, however, it can be expected to be greatest on sites that differ most from the test site.

Despite these limiations, conversion of the progeny test site to a seed orchard appears worthwhile. Seeds produced by the orchard will be used in the area near the test location and this should reduce the impact of single site evaluation. In addition, much of the selection will be based on 20th-year or later measurements, so the probability of high selection age-rotation age correlation will be increased. The current plan for conversion to a seed orchard can be summarized as follows:

Activity	Year	Status at end of activity (Number) Trees per acre	Total trees	Families
Measurement	1974	1,347	5,562	239
1st thinning	1975	870	3,600	228
Measurement, 2nd thinning	1982	435	1,800	50+
Measurement, final thinning	?	109	450	50+

The timing of the initial thinning is essentially an economic matter. Cutting and disposing of a large number of stems is cheaper when they are small. Although retaining all trees is theoretically advantageous, it is assumed that the low intensity of selection will have minimal impact on final gain.

The first thinning will be based on index values derived from the height of an individual tree, mean height of its family, and number of living trees in its family (Falconer 1960). Given the 12th-year estimate of heritability, the predicted response from this form of selection is superior to that expected from selecting only on the basis of a tree's phenotype (mass selection) and far superior to using the family as a selection unit. The thinning will eliminate only 11 of the 239 families and 125 of the remaining families will have 15 or more progeny.

The second thinning will occur at about 20 years from seed when trees begin flowering consistently. It will maintain the plantation's vigor and provide access for seed collection. This thinning will be of moderate intensity, leaving one tree per 100 square feet. The final

thinning to about 8 percent of the stems now living is planned for the early 1990's. Because the objective is to improve the genetic quality of seeds being used as quickly as possible, the final thinning will be earlier if age-age correlations are high.

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REPORT ON THE CROSS PINUS RESIONSA X P. TROPICALIS[1]

Richard B. Hall, David F. Karnosky, and Donald P. Fowler[2]

ABSTRACT.-- Interspecific hybridization was attempted between *Pinus resinosa* and *P. tropicalis*, the only two New World members of the *Pinus* group Sylvestres. Thirteen *P. resinosa* trees at Madison, Wisconsin, and nine trees near Fredericton, New Brunswick, were used as female parents in crosses with *P. tropicalis* pollen. A total of 504 pollinated strobili yielded 115 mature cones, but only 2 putative hybrid seeds contained filled embryos as determined by X-ray photography. The two seeds failed to germinate.

Probably no other commercially important tree species has less intraspecific variability and is more difficult to hybridize with other species than red pine (*Pinus resinosa* Ait.). Fowler and Lester (1970) summarized the small differences among provenances that have been reported for several characteristics of red pine, and they point out that the induction of greater genetic variation through interspecific hybridization has been almost impossible to obtain. Although some genetic gains can probably be made through inter- and intraprovenance selection and breeding, the rate of progress will be much slower than for other species. However, despite past disappointments in interspecific hybridization with red pine, the full range of possible crosses has yet to be adequately tried.

Red pine belongs to the *Pinus* subsection called Sylvestres (Critchfield and Little 1966) or Lariciones (Shaw 1914). All the other members of this taxon are restricted to the Eastern Hemisphere except *Pinus tropicalis* Morelet (tropical pine) which is restricted to two small areas in the Caribbean, the low mountains of western Cuba, and the Isle of Pines (Critchfield and Little 1966).

Much effort has been expended in attempting to cross red pine with other Sylvestres pines (Fowler and Lester 1970). One of the repeated attempts to cross Austrian pine (*Pinus nigra* Arnold) with red pine

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resulted in a few confirmed hybrid seedlings (Critchfield 1963); no success has been achieved with other species. Apparently there have been no previous attempts at crossing red pine with Pinus tropicalis.

Saylor's (1964) karyotype study of the Sylvestres group indicates that the chromosomes of P. resinosa resemble those of P. tropicalis more than they do any other pine. The most striking evidence for this is the similarity in arm ratios for the two smallest chromosomes in each species. This observation, coupled with the lack of other geographically close relatives, suggests the cross with P. tropicalis as a logical step in trying to hybridize red pine.

Little information is recorded on the biology of Pinus tropicalis, but this species must be adapted to a different set of climatic conditions than is red pine. P. resinosa x P. tropicalis hybrids, if produced, would probably not be hardy within the natural range of red pine, but might be directly useful in more southerly latitudes. However, the main advantage would be the introduction of new germplasm that could eventually be incorporated into a hardy organism by back crossing to red pine or by further hybridization with temperate-zone pines of the Sylvestres group.

P. tropicalis has long needles (up to two times longer than P. resinosa), distinctively large needle resin ducts (Shaw 1914), and a seedling "grass" stage (Mirov 1967). These traits should be helpful in hybrid identification. The presence of a grass stage in this species also leads to speculation on possible past hybridization of P. tropicalis with other southern and tropical pines that might make it a particularly rich species in terms of germplasm diversity (Mirov 1967). Aside from the applied tree improvement benefits that the cross P. resinosa x P. tropicalis might yield, it should provide some insight to the evolution of the Sylvestres subsection.

MATERIAL AND METHODS

Pinus tropicalis pollen was obtained from plantations in South Africa and distributed in the United States and Canada by Dr. P. W. Garrett of the USDA Forest Service.

In May 1972, 13 red pine trees growing at the University of Wisconsin Arboretum at Madison and 9 trees growing near Fredericton, New Brunswick, were used as female parents for crosses with P. tropicalis and red pine. An unpollinated control was also included. Cones were harvested in the fall of 1973, the seed extracted, and X-ray photographs taken to determine which seeds were filled and carried a normally developed embryo. Filled seeds were germinated without any pretreatment.

In May 1974, an additional set of five red pine trees at the Holst State Forest in central Iowa were used as female parents. The timing on these pollinations was somewhat delayed, and the peak of strobili

receptivity had passed by the time pollen was applied. Subsequent cone development was observed in the fall of 1974 and the summer of 1975. Cones that mature will be harvested in the fall of 1975.

RESULTS

No hybrid seedlings have been produced to date. A reasonably good cone set resulted from the *P. tropicalis* pollinations, although the number of seeds formed per cone was less than for strobili pollinated with red pine pollen (table 1). In Wisconsin a total of 276 seeds was produced from *P. tropicalis* pollinations, but X-ray analysis revealed that only one of these seeds contained a morphologically normal embryo. All other seeds were empty. The one normal "hybrid" seed failed to germinate.

Table 1.--Results of 1972 red pine pollinations in Wisconsin and New Brunswick

Item	Location	Pollen applied: *P. tropicalis*	Pollen applied: *P. resinosa*
Strobili	Wisconsin	71	12
pollinated[1] (No.)	New Brunswick	433	117
Mature cones	Wisconsin	37	9
produced (No.)	New Brunswick	78	50
Seeds per cone			
Range	Wisconsin	1-38	34-58
Average	Wisconsin	7.5	39.8
Average	New Brunswick	5.2	21.5
Seeds produced	Wisconsin	276	358
(Total No.)	New Brunswick	409	1,075
Filled seeds[2]	Wisconsin	1	304
(No.)	New Brunswick	1 + 103[3]	954
Germination (%)	Wisconsin	0	70
	New Brunswick	0 + 98[3]	94

[1] Excluding strobili lost to insect damage or breakage.
[2] Determined from X-ray photographs.
[3] Two cones in one pollination bag produced 103 full seeds. These seeds proved to be nonhybrids in subsequent tests (see text).

In New Brunswick, pollinations with *P. tropicalis* yielded 409 seeds, of which 104 were full. However, 103 of these full seeds were obtained from 2 cones in a single pollination bag and their hybrid authenticity was dubious. Those putative hybrid seeds, along with suitable control seeds of red pine and *P. tropicalis*, were germinated and transplanted into a greenhouse test. In August 1974 the surviving putative hybrids were examined and compared to the parent species. They were all nonhybrids and indistinguishable from red pine. It was concluded that they resulted

from use of a defective pollination bag or the inclusion of male strobili in the pollination bag. The one supposedly "legitimate" hybrid seed failed to germinate.

The 1974 pollinations performed in Iowa have even less promise of success based on the percent of pollinated strobili that were still maturing as cones in midsummer of 1975. Only 3 of 126 pollinated strobili were continuing to develop, and those were somewhat smaller than the open-pollinated cones on the same trees.

DISCUSSION

The results observed to date are not encouraging. *P. tropicalis* pollen can stimulate conelet and seed coat development in red pine, but it appears that embryogenesis occurs rarely, if at all. Based on a sample of two crossing trials, one in Wisconsin and one in New Brunswick, the viability of the hybrid is also questionable. However, the possibility that red pine can be crossed with *P. tropicalis* should not be abandoned on the basis of this work alone. In these trials only one source of 1-year-old *P. tropicalis* pollen was used and although this pollen showed "normal" germination in distilled water, this is not conclusive evidence that it had retained the ability to function normally *in vivo*.

McWilliam (1959) studied the course of events during the breakdown of seed formation in incompatible pine hybridizations. His work focused on the cross *P. nigra* x *P. resinosa*. In most cases of incompatibility, he observed some penetration of the nucellus by the foreign pollen tubes. In some cases this pollen tube growth halted within the first few months and rapid breakdown of the megaspore followed. Cone abortion was common. When initial pollen tube growth was vigorous, development of the nucellus and megaspore proceeded normally through the first 12 months. But in all cases studied, normal pollen tube growth did not resume in the second spring leading to deterioration of the gametophyte and empty seeds. The failure to complete fertilization was attributed to an adverse metabolic environment for foreign pollen tube growth.

The results of the *P. tropicalis* pollinations indicated that many pollen grains are functioning during the first season, but nearly all fail to complete development the second spring. It was observed that some female parents yielded a higher percentage of matured cones and seeds per cone. For example, 1 female in the 1972 Wisconsin pollinations provided only 4 of the strobili that were pollinated (out of a total of 71), but all 4 strobili matured and yielded an average of 20+ seeds per cone including the 1 filled seed. Much tree-to-tree variation in seed set was also observed among the New Brunswick trees. Such tree- to-tree differences favor the "metabolic imbalance" hypothesis. It is also possible that failure of the *P. tropicalis* pollen to fertilize red pine results from the inability of the germinated pollen to survive the rigorous climates of Wisconsin and New Brunswick.

The fact that the percent of pollinated strobili to continue development in the second year was much lower in the Iowa study is probably more a result of delayed pollination than of tree-to-tree variation or climatic differences.

At this point in the effort to hybridize red pine with tropical pine, several approaches remain to be explored, including: (1) repeating the cross *P. resinosa* x *P. tropicalis* using pollen from South African plantations or preferably from other sources as these become available, and pollinating as many female parents as possible (manipulation of male parentage is not so easy to arrange because all pollen has to be supplied by foreign cooperators); (2) concentrating further effort on those female parents that have previously given good cone and seed set when pollinated with *P. tropicalis* pollen; (3) taking steps to reduce the harsh, over-winter environment that the *P. tropicalis* pollen tubes are exposed to (e.g., using grafted red pine females grown in the greenhouse); (4) making the reciprocal cross on either the native *P. tropicalis* stands or the South African plantations; and (5) using *P. resinosa* - *P. tropicalis* pollen mixes to pollinate either *P. tropicalis* or *P. resinosa*.

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GENETIC VARIATION IN THE HEIGHT-DIAMETER RATIO IN SCOTCH PINE

Jonanthan W. Wright[1/]

ABSTRACT.--A range-wide provenance test including seed from 110 parts of the species' natural range was established in 1961 in three Michigan plantations. The trees were measured in 1973-1974, shortly after crown closure. At that time the plantation in the Upper Peninsula averaged 12.7 ft. tall and 3.3 in. diameter-at-1-foot; the two plantations in the Lower Peninsula averaged 23.9 and 23.2 ft. tall and 6.0 and 6.2 in. diameter, respectively. The average height/diameter ratio (feet/feet) was 54:1 in all three plantations. The six tallest seedlots (30 percent taller than average) were from Belgium, northern France, West Germany, and eastern Czechoslovakia. Their height/diameter ratio varied from 50:1 to 54:1 (differences not significant); all six were among the eight largest in diameter. Thus, selection for rapid volume growth can be done on the basis of either height or diameter. Trees from the north (northern Sweden, Siberia, and the Ural Mountains) grew at very slow to moderate rates (40 to 90 percent of average). Such trees were more slender than average, having height/diameter ratios of 56:1 to 58:1. The stockiest trees (i.e., lowest height/diameter ratios) were from Spain, Greece, Turkey, and northern Italy (average height/diameter ratios of 44:1, 49:1, 50:1, and 50:1, respectively). Those races grew at moderate rates (80 to 100 percent of average) and are among the best for Christmas tree production from the standpoints of foliage color and needle length.

Traditionally in genetic experiments either height or diameter have been measured and separately reported. Sometimes both have been used as the basis for volume estimates but rarely has there been a critical analysis to show the exact relation between the two. This relation concerns the general question of whether growth is controlled by general "growth rate" genes, by specific genes for height growth and for diameter growth, or by a combination of the two types. The

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objective of the study is to answer this important question.

If "growth rate" genes predominate, tree breeding efficiency would improve in several ways: (1) selection of plus-trees for high yield would be simplified; (2) roguing of progeny test seedling seed orchards would be made easier; (3) measurements when trees are taller would be much less costly because only diameters would need to be measured, and (4) the prediction of future genetic differences would be more accurate.

PREVIOUS WORK

A few generalizations can be made from the extensive silvicultural research on diameter growth and stem form. Diameter growth is usually greatest in young trees, primarily because they suffer the least severe competition. In humid regions, rate of diameter growth may be nearly constant until crown closure and then decrease rapidly. It may then increase after thinning, to decrease again as growing space becomes limiting. In young trees the rate of diameter growth is approximately the same at different heights, resulting in a conical bole. With increasing age, diameter growth tends to be greatest near the base of the live crown. Hence, in old forest-grown trees the lower bole may be almost cylindrical.

Genetically, height and/or diameter have been measured more frequently than any other trait. Large differences among seedlots have been found in both traits, but the degree of independence between them has rarely been investigated. One exception is La Farge[2/] who worked with 10 to 12-year-old provenance and with half-sib progeny tests. The average ratio of total height to diameter-breast-high varied from 25:1 to 29:1 (ft/ft) in ponderosa pine, 67:1 to 73:1 in eastern white pine, and 36:1 to 38:1 in Scotch pine. In all three species most of the variation was associated with region of origin, little with differences among stands located a few miles from each other or with differences among the offspring of different trees within the same stand. In ponderosa and eastern white pines the fattest trees (i.e., the lowest ratios) were of southern origin; in Scotch pine the fattest trees were of northern origin. La Farge also studied the ratio between diameter at midheight to that at breastheight. Particularly in ponderosa pine, there were interesting differences in this ratio. It varied from 0.53 to 0.58 (conical stem form) in trees from the interior, and from 0.62 to 0.65 (cylindrical lower boles) in western trees.

2/ La Farge, Timothy. 1971. Inheritance and evolution of stem form in three northern species. Michigan State University Ph.D. thesis, 332 p.

Although much smaller than the differences in either height or diameter, the differences in these ratios were statistically significant and large enough to be of practical importance. La Farge interpreted some of the ratio-differences to be due to differences in cold hardiness; in the northern test area extreme winter cold may have affected height growth more than diameter growth with the result that the least hardy southern trees had the fattest stems. Some he interpreted as due to the presence of separate genes for height and diameter growth.

MATERIAL AND METHODS

The present study is based upon three provenance-test plantations established with 2-0 stock in 1961 as part of the NC-99 regional tree improvement project. The total experiment includes 122 seedlots representing 106 natural stands well distributed over the species' natural range in Eurasia. In the three plantations, 72, 108, and 110 of the seedlots were represented.

The seedlings were planted at a spacing of 8 by 8 ft, with 4-tree plots and 7 to 10 replications per plantation. Necessary weed control was practiced the first 2 years. Survival averaged 90+ percent at each site, but growth was much inferior in northern Michigan (table 1).

Table 1.--Mean heights, diameters, and height/diameter ratios in three Michigan test plantings of Scotch pine

Plantation location	Year measured	Average: Height	Average: Diameter at 1 ft	Average: Height/diameter ratio
		ft	inches	ft/ft
Kellogg Forest, southern Michigan	1974	23.9	6.0	54.6
Rose Lake, central Michigan	1974	23.2	6.4	53.4
Dunbar Forest, northern Michigan	1973	12.7	3.3	53.6

Crowns closed between 1971 and 1973 in the two fastest growing southern Michigan plantations. These plantations were thinned in the winter of 1973-1974 to leave the three best (tallest and/or straightest trees per plot and the trees were pruned to leave six whorls per tree. Crowns have not closed in the northern Michigan plantation, which has been pruned but not thinned.

Total height and diameter, as well as other traits, were measured in the summers of 1973 and 1974 on the two tallest trees per plot. These were generally straight-stemmed trees in which growth rate had not been affected by insect or bird damage. Measurement of the two

tallest trees per plot results in inflated estimates of height and diameter but the values of one seedlot to another are rarely affected by more than 1 percent. Diameter was measured at a height of 1 foot above the ground (or 15 inches if there was a branch whorl). Diameter measurements near the ground were better for biological purposes than diameter measurements at breast height because one plantation was twice as tall as another, and some seedlots were four times as tall as others in the same plantation.

Wright *et al.*[3/] describe variation in other traits and give general recommendations for the choice of Scotch pine planting stock.

An analysis of variance was performed on the height, diameter, and height/diameter ratio separately for each plantation and for all plantations combined.

RESULTS

Mortality averaged less than 10 percent in each of the three plantations. Most deaths occurred the first 2 years after field planting, primarily because of poor planting or weed competition.

The growth data are summarized by variety in table 2. In most varieties, both height and diameter were 70 to 100 percent greater in the Lower Peninsula than in the Upper Peninsula plantation.

Varieties *haguenensis* and *carpatica* from north-central Europe grew fastest at all locations. In the Lower Peninsula they averaged 28 ft tall 13 years after planting and grew at the rate of 2.5 ft per year during the previous 5 years. The six fastest growing seedlots, all from the same two varieties, grew 2.6 ft per year. Thus, they compare favorably with native pine species.

Varieties from northern Eurasia grew only 50 to 80 percent as fast, whether planted in the Upper or Lower Peninsula. Because of their slow growth and because they turn yellow during the winter, they are not planted extensively for either timber or Christmas trees.

Western and southern varieties are preferred for Christmas tree planting because they remain green during the winter and have short needles (table 2). Most grew 75 to 90 percent as fast as the timber varieties. Var. *iberica* from Spain, which remains the greenest during winter and is the favorite of many southern Michigan growers, suffered severe winter injury and consequently grew very slowly in the Upper Peninsula.

3/ Wright, Jonathan W., W. A. Lemmien, J. N. Bright, M. W. Day, and R. L. Sajdak. 1975. Scotch pine varieties for Christmas tree and forest planting in Michigan. Michigan Agric. Exp. Stn. Res. Rep. (In press.)

Table 2.--Height, diameter, and height/diameter ratios of 18 Scotch pine varieties grown in 3 Michigan plantations (data from the 2 Lower Michigan plantations were similar so they were combined)

Variety and place of origin 1/	Height L.P. 2/	Height U.P.	Diameter L.P.	Diameter U.P.	Height/diameter ratio L.P.	Height/diameter ratio U.P.
	Feet		Inches		Feet	
VARIETIES FROM NORTHERN EURASIA						
lapponica N SWE N FIN	14.1	6.7	3.4	1.9	56	45
septentrionalis SWE	19.9	10.5	4.8	2.8	55	50
rigensis S SWE LAT	22.9	14.1	5.8	3.5	55	54
mongolica SIB	20.9	12.2	4.7	2.7	57	53
uralensis URA	23.9	12.3	5.4	3.2	58	55
VARIETIES FROM CENTRAL EUROPE						
polonica POL	27.4	15.5	7.0	3.7	54	55
hercynica W GER W CZE E GER	27.1	15.6	6.7	3.9	54	54
carpatica E CZE	27.6	16.2	6.9	4.0	54	55
haguenensis BEL N FRA W GER	28.3	15.8	7.4	4.0	51	53
pannonica HUN	26.4	12.6	7.1	3.3	51	51
VARIETIES FROM WESTERN AND SOUTHERN EURASIA						
"E. Anglia' ENG	27.1	15.7	7.1	3.8	52	56
scotica SCO	22.7	11.5	5.9	3.0	52	52
iberica SPA	21.6	6.0	6.3	2.1	46	42
aquitana S FRA	22.9	11.6	5.9	3.1	53	54
subillyrica N ITA	24.2	12.4	5.9	3.8	50	51
illyrica YUG	25.3	13.2	6.3	3.4	54	51
rhodopaea GRE	24.0	12.8	6.3	3.3	50	47
armena TUR GEO	24.5	11.9	6.2	3.2	50	51

1/ BELgium, CZEchoslovakia, ENGland, FINland, FRAnce, GEOrgian SSR, GREece, GERmany, HUNgary, ITAly, LATvian SSR, POLand, SCOtland, SIBeria, SPAin, SWEden, TURkey, URAl Mountains, YUGoslavia.

2/ L.P. = Lower Peninsula, Michigan; U.P. = Upper Peninsula, Michigan.

Despite the large differences in growth rate between the Upper and Lower Peninsula plantations, bole form was similar. The height/diameter ratio averaged 54 ft/ft at all three test sites. Northern varieties were the most cylindrical, i.e., had the highest height/diameter ratios. Southern varieties were generally the most conical, having the lowest ratios. Spanish var. iberica was especially noteworthy, with ratios of 46 and 42 in the Lower and Upper Peninsula plantations, respectively. The very low ratio of 42 in the Upper Peninsula plantation was related to the severe winter injury suffered by Spanish trees there. Because of repeated top dieback, they made little height growth but continued diameter growth.

In both height and diameter, differences among varieties accounted for three-fourths of the total genetic variance (table 3). Interactions accounted for most of the remainder. Much of the interaction was caused by the very different performances of var. iberica and var. lapponica in the northern and southern test sites.

Table 3.--Statistical significance of the differences in height, diameter, and height/diameter ratio

Source of variation	Degrees of freedom	Trait: Height	Trait: Diameter	Trait: Height/diameter ratio
		Mean squares		
Variety	16	16,564**	6,482**	6,546**
Seedlot within variety	92	215	137**	667**
Variety x plantation	32	720**	416**	1,983**
Seedlot within variety x plantation	150	184**	68	301
Replication within plantation	14	2,086**	864**	1,526**
Error (= seedlot within variety x replication within plantation)	1,271	94	58	259
		Variance components, as percent of total genetic variance		
Variety		79	74	32
Seedlot within variety		1	6	21
Variety x plantation		9	12	40
Seedlot within variety x plantation		10	8	7

** = statistically significant at 1 percent level.

In the height/diameter ratio, differences among varieties were important but not overwhelming. About 20 percent of the total genetic variance was due to differences among seedlots within the same variety. For example, this ratio varied from 49 to 54 within the fastest growing variety, haguenensis, and from 53 to 56 within the second fastest growing variety, carpatica. Also, there was some interaction in the ratio, due primarily to the different behavior of the slow growing var. lapponica and the cold sensitive var. iberica in the two peninsulas.

POSSIBLE CAUSES OF DIFFERENCES IN HEIGHT/DIAMETER RATIOS

Measurement Technique

For the best estimates of a tree's productivity, measure diameter at ground level and total height. Measuring diameter at a higher point will result in an increase in height/diameter ratios and the effect will be much larger for small than for large trees.

The present data are based upon diameters measured 1 foot above the ground, thus eliminating butt swell. The 1 foot was an appreciable portion of total height only for the slowest growing seedlots planted in the Upper Peninsula. The fact that height/diameter ratios were low indicates that the results were not influenced appreciably by measurement technique.

Competition

The measurements were timed to provide information on bole form of trees grown under competition-free conditions. Actually, crown closure in the two Lower Peninsula plantations had begun in 1971 and was practically complete by the time the measurements were made. Thus, there was some opportunity for competition-induced inflation of height/diameter ratios. However, judging from the stumps of trees cut in thinning and by the similarity of ratios between the plantations which differed markedly in growth rate, competition had not affected rate of diameter growth appreciably at the time of measurement.

Winter Hardiness

Lack of cold hardiness had a demonstrable effect on the height/diameter ratio of var. iberica in the Dunbar Forest plantation. Nearly every winter most trees of this variety suffered dieback of branches or main stem and as a consequence grew little in height. However, most retained live branches below the snow line and continued diameter growth.

Other southern varieties did not suffer visible winter injury in Michigan, but in European experiments have not withstood extreme winter cold. There is a possibility that their growth processes are upset during Michigan winters, and that this upset is apparent only in a

slight reduction in rate of height growth the subsequent season. However, this cannot be demonstrated by a difference in ratio for most southern varieties grown in the Upper versus the Lower Peninsula.

Separate Genes for Height and Diameter Growth

The main purpose of this experiment was to determine whether there are general genes for growth rate or separate genes for height growth and for diameter growth. The results indicate that both types of genes are present. A strong correlation exists between height and diameter, indicating that some genes influence both. But differences in the height/diameter ratio sufficient to cause 10 percent differences in diameter growth among varieties having the same rates of height growth indicate that some genes affect mainly height growth or mainly diameter growth.

PRACTICAL SIGNIFICANCE

Timber Production

Good stem form and high volume production are the primary considerations in timber production. The ideal Scotch pines are those that grow most rapidly in height and in diameter. From the practical standpoint, the most important data on height/diameter ratios are those that concern the fastest growing seedlots. The height/diameter ratio did not differ enough among these seedlots to be of practical importance at the present time. The fastest growing variety, haguenensis, was tallest and had the largest diameter and would, therefore, be selected for planting no matter what the criterion. Of the 122 individual seedlots, those which ranked 1, 2, 3, 4, 5, and 6 in rate of height growth ranked 7, 3, 1, 8, 2, and 6 in rate of diameter growth; they did not differ significantly in either height or diameter. Having both height and diameter data would improve the estimates of genetic gain in volume production, but would not materially change the amount of such genetic gain.

Christmas Tree Production

Christmas tree growers are interested primarily in Scotch pines that retain green foliage color during the winter, have short needles, and grow slowly enough to require a minimum of shearing. For those reasons, southern and western varieties are preferred.

The height/diameter ratio is also of interest to growers who ship long distances, because shipping costs are highest for heavy-boled trees. Several growers have reported that their shipping costs were extraordinarily high for Spanish trees. The present data show that this is true because the Spanish var. iberica has the lowest height/diameter ratio. For trees of equal height, bole diameter is 10 percent greater and bole volume is 20 percent greater for Spanish than for most other Christmas tree varieties.

Volume Production

Some data on volume production of Scotch pine over long rotations in Michigan are already available. They are based on 30- to 40-year-old plantations, probably of German (var. hercynica) origin. For estimates of volume production with genetically improved trees, we must rely on comparatively young experiments such as described here.

To do so requires extrapolation. Under Lower Peninsula conditions, the six fastest growing seedlots (var. haguenensis and carpatica) averaged 29.1 ft tall and are growing at the rate of 2.6 ft per year; 11 percent superior to var. hercynica. Up to age 14 there has been very little change in growth rates of various seedlots, and it is safe to assume that the long term genetic gain in rate of height growth is 11 percent.

For those six seedlots the present genetic gain in diameter growth is also 11 percent or 0.7 inches. However, future diameter growth will be governed more by spacing than by genetic potential because crowns have closed. If these six seedlots were planted for saw logs and subjected to frequent thinning, a continuation of the 11 percent advantage in rate of height growth and rate of diameter growth could be assumed, at least until age 25 or 30. In that case, there would be an approximate 37 percent gain in rate of volume production per tree. If, however, plantations of the improved stock were managed so as to maintain a closed crown canopy, the 0.7 in. diameter advantage by age 14 would be maintained, but future rate of diameter growth would be similar to that already found for plantations of var. hercynica. In that case, volume estimates for the improved Scotch pine should assume 11 percent greater height and 0.7 in. greater diameter for all trees after age 14.

Future Measurement of Test Plantations

The three test plantations described here are easy to walk through. They have been pruned, and diameter measurements are easily made. Early height measurements were not much of a problem but those made at age 14 were time consuming. By age 20, the tallest varieties will exceed 40 ft and individual trees will be 50 ft tall.

Yet such experiments as this must be maintained and may produce their most valuable information after age 20. Growth data will be an important part of that information. The easiest solution will be to measure diameter only and to assume a constant height-diameter relation. That would be moderately satisfactory as regards choosing those seedlots with the greatest average growth rates but would be totally unsatisfactory in comparing future growth rates of northern and southern varieties, in view of the large racial differences in the height/diameter ratio.

SELECTION AND BREEDING EASTERN COTTONWOOD FOR RESISTANCE TO FOLIAGE DISEASES[1/]

J. J. Jokela and W. R. Lovett[2/]

ABSTRACT.--The incidence and effects of *Melampsora* leaf rust and *Marssonina* leaf spot on eastern cottonwood in the central United States are discussed. Yield at age 15 in an Illinois plantation was related to means of leaf-rust scores observed in September of the second and third growing season. An increase of 1 rust score class on a 5-point scale (1=light infection....5=severe infection) reduced yield by about 20 percent. The need for selection and breeding for resistance is stressed and methods for attaining resistance are presented.

Intensive culture of eastern cottonwood, *Populus deltoides* Bartr., is becoming commonplace on the Mississippi Delta and is viewed with increasing interest in the Midwest and elsewhere in the United States. Early results have been sufficiently encouraging to uphold the promise of high yields over short rotations, such as are attained in Europe with selected clones. Nevertheless, it is unlikely that expectations will be fully realized with our natural species--most of which do not warrant intensive culture at wide spacings mainly because of their suscepti-bility to numerous stem and foliage diseases.

Schreiner's (1963) assessment that "poplars, if not the most pest-ridden of the world's important timber species, certainly rank high in this respect" has been largely unheeded in our quest for superior clones of eastern cottonwood. Resistance to specific diseases must be a primary goal rather than a fortuitous result of breeding and selection.

IMPORTANT FOLIAGE DISEASES

Two diseases meriting primary consideration in the central United States are leaf rust caused by *Melampsora medusae* Thum. and leaf spot caused by *Marssonina brunnea* (Ell. et Ev.) P. Magn. Although the

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1/ Study was supported in part by the North Central Regional Project NC-99, "Improvement of Forest Trees through Selection and Breeding," and the Illinois Agricultural Experiment Station.

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effects of the latter disease are obscured by and have been confused with the effects of the better known leaf rust, the two diseases are easily distinguished. Leaf rust is recognized by the presence of yellow-to-orange pustules of urediospores on the upper and often on the lower surfaces of infected leaves. Irregular, dark brown necrotic areas, which may include the entire leaf, and rumpling of the leaf blade are characteristic of leaf-rust infection. Leaf-spot infection is manifest within a few weeks after leafing as discrete reddish brown to purple discolorations on both leaf surfaces. These develop into dark brown lesions that are seldom over 1 mm in diameter. The release of light-colored macroconidia from acervuli in the middle of a dark lesion produces a characteristic ringlike structure. Elongated dark lesions on the veins and petioles are also characteristic. Infected leaves turn yellow to bronze in color and remain flattened in contrast to rusted leaves that darken and rumple. Both diseases progress acropetally in the crown and normally do not reach the tip of the tree until late in the growing season.

INCIDENCE AND EFFECT

Melampsora leaf rust occurs throughout the natural range of eastern cottonwood. The incidence of Marssonina leaf rust is less well known. Recent studies suggest that it is particularly severe in the central United States.

The incidence and severity of Melampsora leaf rust and Marssonina leaf spot on unselected clones of eastern cottonwood of varying geographic origin has been studied in an east-central Illinois plantation on Drummer silty clay loam (Typic Haplaquoll). Rust infection was scored on the following rating system (Jokela 1966):

- Class 1. Pustules not apparent or rare.
- Class 2. Pustules present but not prevalent; little or no leaf drop.
- Class 3. Pustules prevalent on most leaves but not abundant; some leaf drop.
- Class 4. Pustules prevalent and abundant on many leaves; considerable leaf necrosis and leaf drop in the lower portion of the crown.
- Class 5. Pustules so abundant as to appear coalesced; over 50 percent leaf drop.

Leaf spot was scored on a similar rating system except that it was based on the presence of lesions rather than pustules and on the yellowing or bronzing rather than necrosis of the foliage.

Trees were scored on September 24, 1974 (table 1). Each plotted point above the blocks on the diagonal or equality line represents a clone more severely attacked by leaf spot than by leaf rust. Most clones of

Table 1.--Incidence of Melampsora leaf rust and Marssonina leaf spot on clones of eastern cottonwood of southern, central, and northern seed origins in a 5-year-old plantation, September 24, 1974, Urbana, Illinois

Leaf-spot score	Mississippi (*)						So. Illinois (•) and Missouri (+)						No. Illinois (x) and Minn.-Wisc. (0)					
	Leaf-rust score					Percent of clones	Leaf-rust score					Percent of clones	Leaf-rust score					Percent of clones
	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5	
5						-						-	o	o o x x o o	o x o x o x	o o		39
4		*	*			28		+ •	+ • • •		+ • +	21	x	x o o o x	x o o o o o x	x o o o x	o o	49
3	* *		*			43	• + •	+ •	+ + • + + • + +	+ • + + • +	• •	51			o o o o	x		12
2		* *				29		+	+ + • + +	+	+ • • • +	28						-
1						-						-						-
Percent of clones	28	43	29	-	-	100	7	12	39	16	26	100	5	29	41	20	5	100
Basis	7 clones (11 trees)						43 clones (67 trees)						41 clones (67 trees)					

northern origins are in this category, whereas most trees of central origin are more severely infected with leaf rust. Observations made over several years have shown that clones of southern origin are not severely attacked by either pathogen until late in the growing season.

The primary effect of either disease is premature defoliation. In Illinois this may occur 2 months before the end of the normal growing season and is sufficiently extensive and severe to virtually preclude the development of yellow autumn coloration on eastern cottonwood. Premature defoliation caused by leaf rust has been associated with loss in vigor, lessened winter hardness in colder climates (Nagel 1949, Meiden and Vloten 1958, Peace 1952), a predisposition to attack by other pathogens (Nagel 1949, Schreiner 1959), and root starvation.[3/]

The economic impact of foliage diseases has not yet been thoroughly evaluated in American plantations because until recently there has been little interest in intensive culture of poplars. The contention that leaf rust infection occurs too late in the growing season to affect growth is unfounded. Wilcox and Farmer (1967) found high negative correlations between first-year rust reaction and second-year growth in height and diameter in a Mississippi plantation of eastern cottonwood. Chiba and Nagata (1973) found similar correlations in *P. maximowiczii* between rust scores made in the nursery and height at 8 years of age.

The cumulative effect of annual rust infections on growth and survival is being studied in a clonal and seedling plantation established in 1960 on a bottomland site in east-central Illinois for the purpose of studying heritable variation in eastern cottonwood. Only results obtained in the seedling planting are reported here. This plantation was established with 20 1-year-old seedlings selected at random from each of 22 progenies of southern Illinois origin, 38 progenies of west-central Illinois origin, and 32 progenies of east-central Illinois origin.

All trees were scored for rust infection in early September of the second growing season and again in late September of the third growing season. Subsequent growth and survival measurements have been correlated with the means of these two rust scores. Significant differences in height and survival that were related to mean rust scores were already present at 7 years of age when the first height and survival measurements following rust ratings were made. These differences have increased with age and have been most pronounced on the trees of southern Illinois origin and least pronounced on trees of east-central Illinois or local origin.

3/ Personal communication with C. W. S. van Kraayenoord.

The relation between mean rust score and diameter squared x height, a relative measure of tree volume, at 15 years of age is shown in figure 1. The solid line shows the relation for trees that survived through the 15th growing season following planting. The relation shown by the broken line is a better indicator of yield because it accounts for mortality. Accumulated mortality to age 15, which averaged about 15 percent of the trees in the lower three rust score classes, increased to 33 percent of the trees in rust class 4 and to 50 percent in rust class 5. The essentially linear relation between D^2H and rust score suggests that an increase in one rust score class reduced yield at age 15 by about 20 percent.

Information on the economic impact of Marssonia disease on eastern cottonwood in American plantations is not presently available. Premature defoliation caused by this disease occurs earlier and is at least as extensive in the central United States as that caused by leaf rust, hence there is reason to expect that economic losses may be as serious as those caused by leaf rust. Marssonina leaf diseases have caused severe economic losses on euramericana poplars in Europe (Meiden 1962, Castellani and Cellerino 1964).

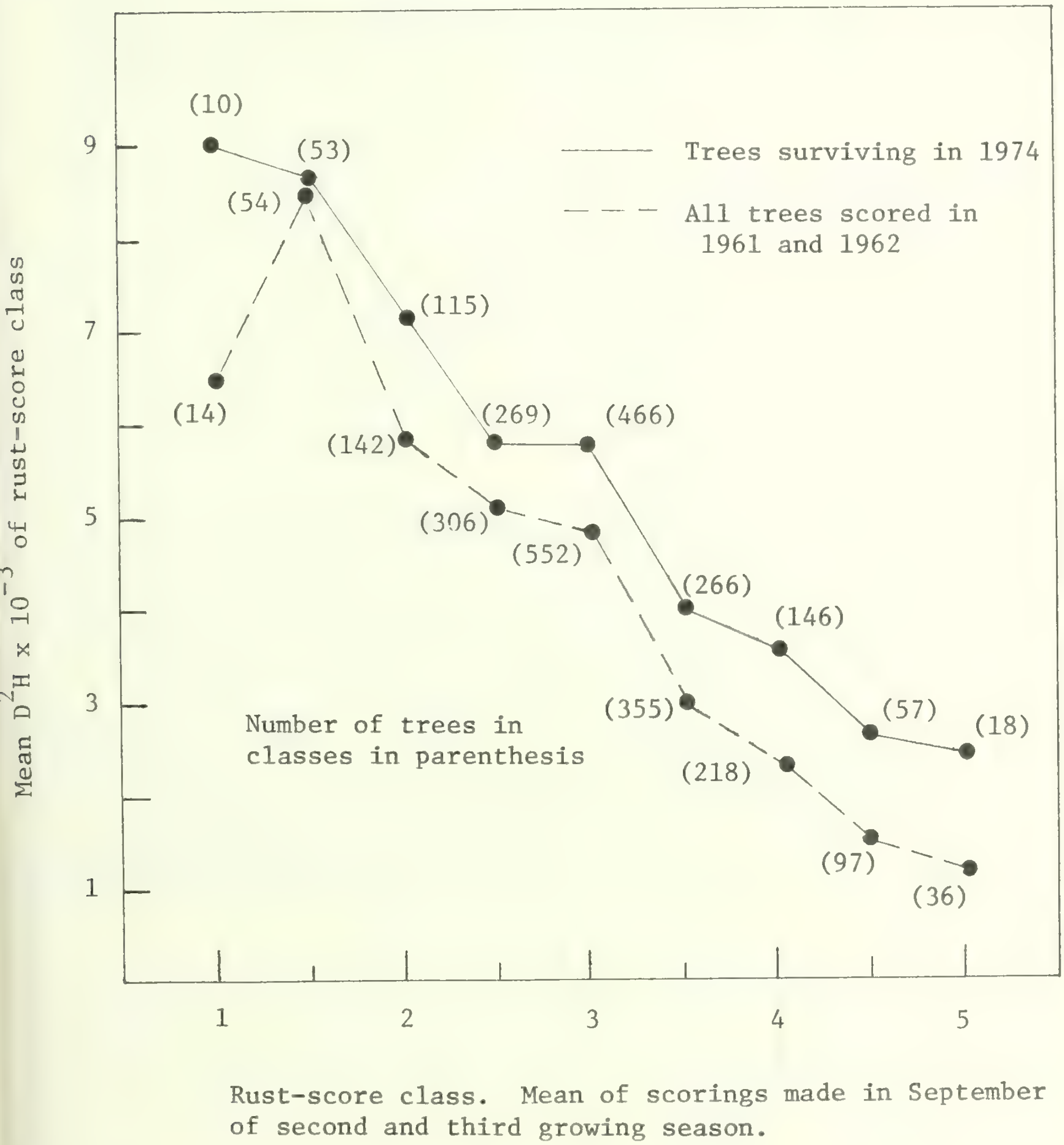
SELECTION AND BREEDING

The wide range of resistance to Melampsora leaf rust among geographic origins, progenies, and clones of eastern cottonwood, and the reliable and rapid assessment of rust reaction argues well for the development of resistant clones and varieties.

Geographic Origin Tests

Evidence from NC-99 tests suggests that utilization of geographic variation is one approach to obtaining rust resistance. In the Ohio test (Thielges and Adams 1975), trees of Missouri origin were more resistant than were trees of local or other midwestern origins. In the Illinois test most clones of Louisiana or Mississippi origin remained practically rust free until very late in the growing season. Correspondence with world-wide recipients of eastern cottonwood seed distributed by the Poplar Council suggests that seed from certain origins has yielded large numbers of resistant trees. This type of uniform resistance appears to be due to an interaction between seed origin and environment and it may be specific to the locations of the planting. Northward movement of seed enhances rust resistance but incurs the risk of planting trees where they are not winter hardy. Because a reliable assessment of winter hardiness requires many years. NC-99 test plantings, which are already 10 years old, are a logical place to search for this type of resistance. Resistance to Marssonina might be selected for simultaneously. We have selected a number of clones of Mississippi and southern Illinois origins that are field

Figure 1.--Relation between Melampsora leaf-rust score and diameter squared x height of trees of Illinois seed origin in a 15-year-old plantation in central Illinois



resistant to both diseases, are rapid growers, and appear to be hardy in central Illinois.

Progeny Tests

Observations of numerous open-pollinated progenies do not support the idea that seed collections from untested, rust-resistant wild trees will necessarily yield rust-resistant progenies. This is not to say that differences among open-pollinated progenies do not exist. On the contrary, we have found progenies that are mostly field resistant but we have never been able to demonstrate a correlation between the resistance of the female parents and the progeny means.

Results of a test of open-pollinated progenies are given in table 2. All progenies are of southern Illinois origin with the exception of those from seed collections made in the central Illinois counties of Vermilion, Henderson, and Hancock. Most trees in Progeny 73-002, which had the lowest mean rust scores on both dates that scorings were made, were field resistant (i.e., rust scores of 1 or 2 on September 6). More than 50 seedlings with a rust score of 1 could have been selected in this progeny and Progeny 73-001, which had the next lowest mean rust score. Less than 20 rust-resistant seedlings were found in the remaining 20 progenies.

The tendency for progenies to be either lightly or heavily rusted suggests that progeny screening tests conducted in the nursery would be useful in selecting parents that yield a high proportion of resistant individuals. Fifty to 100 seedlings per progeny, with 3 replications, would be sufficient to identify resistant progenies. On the basis of observations reported in table 2, one might expect 1 to 3 percent of the progenies to contain sufficient numbers of resistant individuals to warrant large seed collections from their parents in subsequent years.

A small to moderate size program such as this should yield hundreds of resistant individuals for establishing clonal tests to assess growth and other traits. A major drawback, however, is that *Marssonina* infections appear to be too light in the nursery or in 1 or 2-year-old plantings on new sites to allow reliable assessment of resistance to this disease.

Controlled Pollination

Hybridization studies begun by Muhle-Larsen (1970) and continued by Steenackers (1972a, 1972b) show great promise for obtaining resistance to several diseases.

Table 2.--Mean rust scores on September 6 and October 4, 1973, of open-pollinated progenies sown in Union State Tree Nursery, Jonesboro, Illinois, on June 20, 1973

Progeny (UIFG No. 73-)	Seed origin		Mean rust score[1/]	
	Nearest town	County	Sept. 6	Oct. 4
001	Golconda	Pope	3.0	3.4
002	Golconda	Pope	1.0	1.4
003	Joppa	Massac	2.8	3.0
005	Grand Chain	Pulaski	3.0	3.6
006	Grand Chain	Pulaski	3.5	4.6
008	Thebes	Alexander	3.8	4.8
011	Georgetown	Vermillion	1.5	2.4
012	Oquawka	Henderson	3.0	4.1
013[2/]	Carthage	Hancock	3.5	4.1
014	Brookyln	Schuyler	3.0	4.7
016	Chester	Randolph	3.0	3.4
017	Rockwood	Randolph	3.0	4.1
018	Jones Ridge	Jackson	3.2	4.0
019	Valmeyer	Monroe	3.5	5.0
020	Valmeyer	Monroe	2.8	3.1
021	Rockwood	Randolph	3.8	4.4
022	Rockwood	Randolph	3.2	4.0
024	Grand Tower	Jackson	3.0	4.1
026	Ware	Union	3.5	4.0
027	Reynoldsville	Unioon	3.2	4.3
028	McClure	Alexander	3.8	4.4
029	Cache	Alexander	4.0	4.7
All sources			3.1	3.9

1/ Means for September 6 and October 4 are averages of 4 and 7 plot means, respectively, 50 to 200 trees per plot.

2/ UIFG-68-J18-00. Selected in 1968 for resistance to *Melampsora* and *Marssonina*.

Assortative matings of *Melampsora* resistant and susceptible eastern cottonwood were studied by Lovett (1975). He found significant differences among mating types. However, these differences were not as large or in the direction one would expect if resistance was largely controlled by additive genes. The results supported Jokela's (1966) heritability studies, which suggested that much of the genetic variation in susceptibility to *Melampsora* within eastern cottonwood was non-additive. Controlled pollinations will be useful and necessary in

combining resistance and other desirable traits. Until more is known about the inheritance of specific traits and of general and specific combining abilities, however, selection of wild types appears to be a more practical approach.

Selection of Resistant Phenotypes

The most promising approach to obtaining resistant clones for immediate use is to select phenotypes from natural stands in midfall just before the first killing frost. At this time trees highly resistant to both *Melampsora* and *Marssonina* diseases are strikingly conspicuous because only they will have a full complement of healthy green foliage. This method also allows simultaneous selection for tree form and, to a limited extent, growth rate.

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GENETIC CONTROL OF RESISTANCE TO HYPOXYLON INFECTION AND CANKER DEVELOPMENT IN POPULUS TREMULOIDES[1/]

Fredrick A. Valentine, Paul D. Manion and Kathleen E. Moore[2/]

ABSTRACT.--The responses of 24 families of *P. tremuloides* (6 groups of 4 maternal half-sibling families each) to 4 sources of *Hypoxylon mammatum* were observed. Three mechanisms of resistance to the disease were studied: (1) callus formation, (2) branch death, and (3) resistance through retardation of canker growth. Resistance by callous formation is due to a hypersensitive response of the host to the pathogen. Little variation exists in the nature or time of the host response, but the pathogen's ability to elicit the host response, expressed as incidence per inoculum, varies from about 3 to 35 percent. Evidence suggests that a few major genes control this trait and are the basis for Mendelian ratios within families and discrete differences between groups of half-sibling families. Resistance by branch death occurs at a low incidence (8.3 percent) and death is due to the canker encircling the branch. Heritability estimates are low, 0.075 or less in response to the four inocula and 0.027 for all data. These are probably underestimates because all potentially resistant phenotypes most likely have not been expressed 4 months after inoculation. The third form of resistance, retardation of the spread of the pathogen, is measured as canker length. h^2 is low for three inocula ($\leq$ 0.074), but reasonably high (0.254) for the fourth source.

The best breeding methods for disease-resistant forest trees may be those concerned with breeding for "nonspecific" or horizontal resistance. This type of resistance functions against all pathogenic races or biotypes and is generally considered polygenic. "Specific resistance" functions against individual races of a pathogen and is also called major gene resistance, hypersensitivity, and vertical resistance. It is controlled by single or a small number of genes. A knowledge of the genetic control of resistance is necessary if we are to design an effective tree breeding program.

1/ Miss Moore completed the Veldman computer analysis of canker lengths as an undergraduate research problem.

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Preliminary results (Valentine and Manion 1972, Manion and Valentine 1974) suggest that resistance to Hypoxylon canker in trembling aspen (Populus tremuloides Michx.) and bigtooth aspen (P. grandidentata Michx.) is polygenic. In this report we show that much genetic variation exists in factors affecting (1) infection of the host by artificial inoculation with Hypoxylon mammatum (Wahl.) Mill. (syn. H. pruinatum (Klot.) Che), (2) prevention of the establishment by rapid death of host tissue, or (3) isolation through callousing and retarding canker enlargement.

MATERIAL AND METHODS

We used 7-year-old P. tremuloides at the Tully Genetic Field Station, Tully, New York (fig. 1). Following Comstock and Robinson's Experiment 1, each of six pistillate-flowered trees was crossed to a random sample of four staminate-flowered trees to give six maternal half-sibling groups of four families each. One-year-old seedlings were planted in 1968 in a randomized complete block design with three blocks and nine trees per family per block.

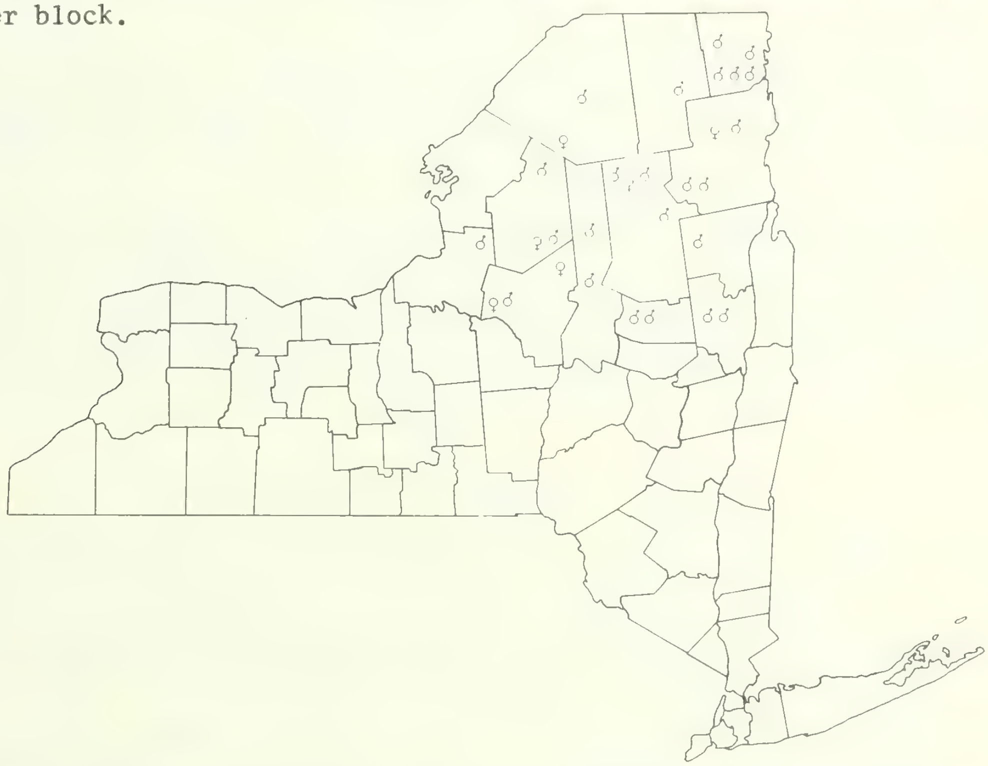

Figure 1.--Geographic locations of the six trees serving as female parents (♀) and the 24 trees as male parents (♂) in the northern New York population of P. tremuloides.

In June 1974, four 2-year-old branches, approximately 1.5 m from the ground, were inoculated with H. mammatum mycellum grown for 2 weeks at 30°C on moist sterilized wheat. Six-mm circular patches of bark were removed with a cork borer and one piece of H. mammatum-infested grain placed in each wound. The inoculations were wrapped with parafilm "M". Four pathogen sources were used: (1) a "Baldwinsville, New York" culture (French and Manion 1975, isolate 208 M), (2) a "Tully" culture originating from a single ascospore (Hsu 1975, isolate 4B19 #5 set 1), (3) a "Shiawassee County, Michigan" culture, and (4) a "Heiberg Forest" culture (French and Manion 1975, isolate 608 M). The four strains were used to inoculate branches with north, east, south, and west exposures, respectively. Some trees and branches were missing so that there were unequal numbers of inoculations in the families. Four months later the lengths of the resulting cankers were measured. Cankers surrounded or covered by callous tissues and cankers on branches that had died were noted. Cankers on broken branches (8.5 percent) were counted but not measured.

We used the method of Robertson and Lerner (1949) to estimate the heritability of resistance by callousing and by branch death (also see Dempster and Lerner 1950). The method requires the calculation of the average genetic relation (r^G) of the members of each family making up each half-sibling group. For this we used the method of Osbourne (1957).

Heritability estimates for canker length were based upon a three-way ANOVA (Veldman 1967). The methods of King and Henderson (1954) and Becker (1975) were used to calculate the coefficients for partitioning variance when there are unequal numbers of observations per family. These were then applied to the ANOVA results to estimate the covariance of maternal half-sibling groups and the phenotypic variance.

RESULTS

Resistance Through Callous Formation

Genetic factors control all three mechanisms of resistance to cankering

The results of Chi-square Tests of Homogeneity for the responses of the six half-sibling groups to each of the four inocula are statistically nonsignificant except for the Tully data, table 1, therefore shows group means only. In the Tully results, three of the six means are outside the range of the $\bar{x} \pm 2s$. Some differences were also evident in the Baldwinsville data, with two mean values outside the $\bar{x} \pm 2s$, but the probability value for the Chi-square test is greater than 0.20.

Table 1.--Incidence of resistance by callousing among maternal half-sibling aspen families inoculated with four sources of *Hypoxylon mammatum*

(In percent)

Item	Source of inoculum			
	Baldwinsville, New York	Tully New York	Shiawassee County, Michigan	Heiberg Forest, New York
All families	12.6±1.4	3.3±0.8	15.7±1.5	34.9±2.0
Total number of inoculations	557	552	573	567

The heritability estimates were calculated but the values are small with large standard errors or are negative, so they have not been given. The estimate for the Tully data is the largest, but is only 0.068 and its standard error 0.067.

Male effects within maternal half-sibling groups were considered for the Heiberg data because they include the highest incidences of callousing. If segregations for one or more "major" genes for callous formation occur in the population, Mendelian ratios may be inferred from these data (table 2). The four families in each group separate into two or three different frequencies. Groups CA107, HA313, and ES107 exhibit two levels, with the lower incidence, ranging from about 20 to 30 percent, about half that of the higher incidences that range from about 40 to 50 percent. In the other three groups, one or more families occur with either a "low" or a "high" incidence of callousing, but in addition, families with a frequency intermediate to these also occur. Minor variations also can be seen among the half-sib groups, with the SL209 group lower than the others.

Resistance Through Branch Death

Responses to the Baldwinsville and Tully inocula are large, ranging from 0 to 13.4 percent for Baldwinsville and from 6.8 to 19.5 percent for the Tully isolate (table 3). In the test for homogeneity the Chi-square values are statistically significant. The variation in the other two inocula is much less, and the Chi-square results are not significant.

The mean frequency of branch death for the four inocula ranges from 4.6 percent for the Heiberg source to 11.6 percent for the Tully source. The tests for homogeneity, however, suggest that there are no real differences in the responses of the other half-sibling groups to the four pathogen sources (except for the SL209 group). The data for the four inocula for each half-sib group were then pooled and a Chi-square test used to analyze the variation in the mean incidences among the six groups. Maternal parents SL209 and LE208 appear to contribute genes

Table 2.--Incidence of calloused cankers in response to the Heiberg inoculum in each of the four half-sibling families constituting each of the six maternal groups (percent incidence is shown by the position of the male parent tree designation along the vertical axis

Calloused cankers (percent)	Maternal groups of half-sibling families (common female parent)					
	SL209	LE208	OA107	OA201	HA313	ES107
55						
50						CL202
				HE202		
					ES111	
45						
		HA312			FU111	
	OS109	CL106				
			CL104			
40			SL112			
			HA308			
	ES201			SA113		
35		CL306				
				CL110		
30						
						HA209
	SL111	WA105			ES202	OA102
25					LE108	
			FU109	FR212		
						HE109
20						
	LE201					
15						

for resistance, especially in response to the Baldwinsville and Tully inocula, and the HA313 parent appears to lack these genes because its progeny exhibit a low incidence of branch death.

Table 3.--Incidence and heritability of resistance by branch death among maternal half-sibling aspen families inoculated with four sources of *Hypoxylon mammatum*

(In percent)

Item	Source of inoculum: Baldwinsville, New York	Tully New York	Shiawassee County Michigan	Heiberg Forest New York	Half-sib mean incidence	Test of homogeneity: χ^2 (d.f.=3)	Probability
Half-sib Family							
SL209	12.2±3.6	19.5±4.3	7.8	1.6	11.0±1.7	13.130	<0.01
LE208	13.4±3.8	18.9±4.1	9.8	5.0	12.4±1.9	7.193	>.05
CA107	5.7±2.5	7.4±2.7	7.9	3.0	6.2±1.3	2.374 1/	>.95
CA201	8.0±2.9	8.0±2.9	8.9	8.2	8.2±1.5	0.085	>.99
HA313	0	6.8±2.9	4.2	5.8	4.1±1.2	5.396 1/	>.10
ES107	7.6±3.0	9.0±2.9	7.1	4.5	7.0±1.4	1.609 1/	>.70
All families	8.0±1.2	11.6±1.4	7.7±1.2	4.6±1.1	8.3±0.6		
Test of Homogeneity value of χ^2 (d.f.=5)	11.864	15.155	1.905	1/ 4.115	17.934		
Probability	<0.05	<0.01	>0.80	>0.50	<0.01		
Heritability	0.005±0.066	0.075±0.076	Negative value	Negative value	0.027±0.026		

1/ Yates adjustment was applied to these data due to expected values of 5 or less.

The variability among half-sib families could represent random sampling variation. This, however, does not appear to be the case because the callousing frequency in 20 of the 24 families is outside the range, p ± 2s (30.9 to 38.9 percent), for the Heiberg results. The three families that do occur within this range are "intermediates" in their groups, and the fourth, SL209 x ES206, is a high incidence family. The observed distribution is bimodal, with the "high" incidence families comprising one modal group and the "low" incidence families, the other.

The heritability estimates for the Baldwinsville and Tully strains are low and have large standard errors, and are negative for the Michigan and Heiberg data (table 3).

Resistance Through Retardation of Canker Growth·

The size of cankers varies with the four pathogen sources and among the six maternal half-sibling groups (tables 4, 5, and 6). The ranking of the four inocula based on canker size is very consistent. The mean is smallest for Heiberg (6.02 cm), followed by Baldwinsville (6.34 cm), Tully (7.34 cm) and Michigan (7.76 cm). With only three exceptions this ranking is also the same for the six individual half-sib groups (table 4). The differences among maternal half-sibling groups is also large and is statistically significant for all inocula except Heiberg ("Females" in tables 5 and 6).

Table 4.--Mean canker length 4 months after inoculation for each of the four sources of pathogen (each family mean for each inoculum is based on between 55 to 85 cankers)

Half-sib	Source of inoculum: Baldwinsville, New York	Tully New York	Shiawassee County Michigan	Heiberg Forest New York	Pooled data: Mean	Pooled data: No.
	Centimeters					
SL209	6.28	7.99	7.81	6.09	7.16	285
LE208	6.22	7.68	7.87	6.50	7.16	300
OA107	5.94	6.43	7.10	6.10	6.43	308
OA201	6.16	6.47	7.32	5.99	6.48	300
HA313	6.13	7.52	7.81	5.43	6.86	257
ES107	7.32	7.94	8.59	6.00	7.58	305
Mean	6.34	7.34	7.76	6.02	6.91	1,755
No.	443	475	457	380		

Table 5.--ANOVA for canker lengths 4 months after inoculation and the heritability estimates based on the combined data for the four sources of inoculum

Source of variation	d.f.	Mean square
Between families	23	22.705**
Females	5	56.565**
Males W/N females	18	13.299**
Blocks	2	16.964*
Inoculum sources	3	260.198**
Families X blocks	46	6.323
Families X inocula	69	6.723*
Blocks X inocula	6	15.965**
Families X blocks X inocula	138	4.466
Within families (error)	1,468	5.107
Weighted coefficient for variance components:		
t	5.92	
Estimates of heritability:		
With the inocula effects included in σ_p^2	0.083	
Without the inocula effects and the interactions with other main effects in σ_p^2	0.109	

* Statistically significant at the 5 percent level of probability
** Statistically significant at the 1 percent level of probability

Table 6.--ANOVA results for canker lengths 4 months after inoculation and estimates of heritabilities for each of the inoculum sources

Source of variation	d.f.	Baldwinsville, New York	Tully New York	Shiawassee County Michigan	Heiberg Forest New York
		Source of inoculum (mean square)			
Blocks	2	21.162**	12.629	24.001*	7.217
Females	5	16.206**	36.002**	17.891*	6.485
Males W/N females	18	9.313**	7.969	15.474**	2.666
F-M X Blocks	46	5.398	5.661	5.719	3.306
Within families d.f.		371	403	385	308
m.s.		4.521	5.061	6.824	4.357
Weighted coefficients of variance components:					
k_1		18.168	19.513	18.840	15.611
k_2		19.274	20.597	19.604	16.461
k_3		73.574	78.993	75.967	63.159
Estimates of heritability		0.074±0.119	0.254±0.224	0.015±0.090	0.058±0.062

* Statistically significant at the 5 percent level of probability
** Statistically significant at the 1 percent level of probability

Other significant results include block effects, the interaction between blocks and inocula, and the interaction between families and inocula. Because the variation in canker sizes associated with each pathogen source is similar in each of the half-sib groups, it is not likely that a Female and Inoculum interaction is an important part of the Families X Inocula interaction.

We used the weighted coefficients of the variance components to determine the heritability of canker length (bottom tables 5 and 6) (King and Henderson 1954, Becker 1975). The difference between the two heritability estimates in table 5, h^2 = 0.083 and h^2 = 0.109, is the consequence of including the variance components due to differences in inocula sources and its interactions only in the first estimated phenotypic variance. All of the heritability values are small except for the Tully inoculum (table 6) which is 0.254. All also have large standard errors.

DISCUSSION

Three mechanisms confer resistance to hypoxylon cankering in the northern New York trembling aspen population: (1) callous formation, (2) branch death, and (3) resistance through retardation of canker growth. On the basis of individual inocula the estimates of the heritabilities for all three traits are low: 0.064 or less for callous formation, 0.076 or less for branch death, and 0.074 or less for retardation of canker growth. For the pooled data of all four inoculations on each tree, h^2 are 0.027 and 0.083 for branch death and retardation of canker growth, respectively, but $h^2 = 0.109$ for canker growth retardation if variation due to inocula and its interactions with other main effects are not included in the estimate of the total phenotypic variance.

Callous formation is rapid and similar to a hypersensitive reaction, occurring before a measurable canker developed in 314 (83.5 percent) of the 376 calloused wounds or cankers. The "late" calloused cankers ranged up to 7 cm in length, with the incidence of callousing decreasing with an increase in length of the canker. The frequency distribution according to canker size when calloused, however, does not fit a Poisson distribution ($\chi 2 = \infty$, d.f. = 4., $P<0.001$). This type of early response of the host is characteristic of hypersensitive reaction, generally controlled by one or a few genes (Williams 1975).

The incidence of callousing differs markedly for the four sources of inoculum (table 1), which suggests that variation is due to the pathogen and not the host. Differences in the incidence of callousing is small and not significant (except the Tully inoculum). (Tully data are limited--only 18 calloused cankers of 552.) This suggests that the host genotypes for a gene or genes controlling the callousing response to the fungus are essentially alike. This limited variation is also responsible for the low heritability values because they are dependent upon the variance between half-sib groups.

The variations in the callousing response of each half-sib group to each of the four inocula are large and highly significant, with a high incidence exhibited by all six groups in response to the Heiberg inoculum, an intermediate incidence in response to the Michigan and Baldwinsville source, and a low incidence in response to the Tully inoculum. The greatest variation, therefore, exists in the pathogenicity of the fungus, with very little variation in the host reaction to a particular pathogen phenotype (table 1).

The sizes of calloused cankers also suggest that the host response to the pathogen is the same regardless of the source of the inoculum. The frequencies of "early" (calloused canker length = 2 cm) and "late" (>3 cm) callousing were tested for homogeneity using the Chi-square method. The "late" cankers in the 3 to 7 cm length classes were pooled. The results are nonsignificant ($\chi 2 = 7.402$, d.f. = 3; $0.10 > P > 0.05$). The Chi-square

value is large and primarily represents the contribution of the limited data for the Tully inoculum (11 "early" and 7 "late" cankers). If we include only the data for the other three inocula, the variation is small ($\chi 2 = 1.159$, d.f. = 2, $P > 0.50$). Therefore, the host response to the pathogen is the same regardless of the overall incidence of the callousing response, with the frequencies of "early" and "late" responses 84.6 percent and 15.4 percent, respectively.

The results support the hypothesis that callous formation is controlled by a few gene loci that are "turned on" in host tissue by the presence of pathogen genotypes with a given level of virulence. Clear-cut Mendelian ratios will not necessarily be observed, however, because this appears to be a threshold-type response. Nevertheless, sharp, distinct differences in the frequencies of callousing among the four families composing a given half-sib group would be expected. The two or three different frequencies in response to the Heiberg inoculum support this (table 2). The 11 families comprising the high incidence level of callousing in the 6 groups may represent the expectations from a testcross, namely a 1:1 Mendelian ratio. The nine families exhibiting the low level could represent an incidence of 25 percent callousing, the expectation if callousing is a recessive trait and the parents are both heterozygous. We tested the goodness of fit of the observed results to that expected for each of the 11 "high frequency" and the 9 "low frequency" families if they represent expected Mendelian ratios of 1:1 and 1:3, respectively, (calloused to noncalloused); all were nonsignificant. We also compared the observed incidence for each family to the range p ± 2s, for each of the two Mendelian expectations. In all cases, the observed incidence was within the expected range. These results clearly support the hypothesis that callousing is due to a single gene in the "high" and "low" incidence families.

The intermediate frequencies exhibited by the four families in the SL209, LE208, and OA201 groups, cannot be explained as easily. It appears that resistance by callousing is not always a simple Mendelian trait, but rather, it is controlled by a more complex genetic system. Nevertheless, sharp, distinct differences that recur among related families are most easily explained by the segregation of major genes contributed by the common parent, in this case the female parent. Confirmation of this hypothesis must await further experimentation.

We expected heritability estimates to be high; instead, they were low. This is because the estimates were not based upon individuals or even family means for estimating additive genetic variance, but upon the variation among half-sibling group means around the population mean. The group mean, in turn, represented the average incidence in the four half-sibling families comprising that group. Because variation among mean values was low, heritability values were low.

Resistance by death of the infected branch does not appear to be a hypersensitive host reaction, but rather the response resulting from the spread of the canker to girdle the branch. The response is not as rapid as callousing. Only 13 (8.4 percent) of the 155 branches that died, did so before a measurable canker developed, i.e., greater than 2 cm in length. The incidence is so low that little information on the size of cankers at the time of branch death or the frequency distribution can be gleaned from the individual family data, the half-sibling group data in response to each inoculum source, or even the pooled data for each half-sib group in response to all four inocula. Data pooled for all half-sib groups for each inoculum or for all data approximate the normal distribution, with the modal class almost always including the average length of all living cankers (table 4). More branches were being girdled when these results were obtained so later field scoring should provide information on how long after infection this type of resistance can act to prevent disease development.

The variation in branch death among the six half-sibling family groups in response to the Baldwinsville and Tully inocula is statistically significant. There is little variation in response to the other two sources. Correspondingly, the largest h^2 values, 0.075 and 0.055, were obtained in response to Tully and Baldwinsville sources, with negative values for both the Michigan and Heiberg sources. The incidence in response to the Heiberg source was very low, only 17 among 369 cankered branches. Therefore, even though the Yates' adjustment was applied, the results may not be reliable.

Though small, differences probably do exist among pathogen sources (table 3). This is supported by the pattern in the frequencies of branch death in response to the four inoculum sources by each of the half-sibling groups. The lowest incidence in all groups except one, HA313, is in response to the Heiberg source. The incidences in response to Baldwinsville and Michigan are generally intermediate; and to the Tully source, the highest for four of the six half-sib groups. The lack of statistically significant results in the Chi-square Tests of Homogeneity for all but SL209 probably is a consequence of three factors: (1) the low incidence of this form of resistance, (2) a small variation in response, and (3) the numbers of cankered branches in each half-sib group for each pathogen source. Though these numbers range from 52 to 100, they are not large enough to show a difference among inoculum sources. The numbers for the branch death data are smaller than for callousing because calloused cankers are not considered candidates for branch death. This also accounts for the lowest numbers of cankers for the Heiberg data because that inoculum resulted in the highest callousing frequencies. Another point regarding pathogen variation should be made: if the pathogen variation is real, the heritability estimate based upon the pooled data (table 3) would be meaningless.

Although not as convincing as the callousing data, the branch death results appear to support the hypothesis that this is a polygenic control system with a low heritability. If the trait is controlled by many loci, a small amount of variation in incidence of branch death is expected among the four half-sib families. Sharp differences, as were found in the callousing results, would not be expected. Branch death in resistant trees generally occurs in all families with the exceptions almost entirely in either the HA313 families in response to all four inocula or among the families in all six half-sib groups in response to the Heiberg inoculum. In these cases, however, the incidences of branch death are low and the absence of branch death is probably due to chance variation. The highest frequencies of branch death, such as the SL209 and LE208 in response to the Baldwinsville and Tully inocula, are evenly scattered among the four half-sib families, but they do exhibit small variations. The heritability estimates obtained in this study are probably underestimates of the true values because it is not likely that all branches had died when these observations were made at 4 months. Results from further field observations should resolve this point.

The differences in canker lengths 4 months after inoculation appear to represent true differences among the six groups of maternal half-sibling families (tables 4, 5, and 6). If short canker length can be equated to resistance by the host and long cankers to susceptibility, the HA303 groups appear the most resistant, the OA107 and OA201 groups range from intermediate to resistant, SL209 and LE208 are generally intermediate but tend toward susceptibility and ES107 is the most susceptible. This order of ranking is similar for the pooled data for each maternal half-sib group and for the mean values for each inoculum. There is little doubt that this trait is controlled by a number of genes that exhibit a small amount of additive genetic variance. It exhibits general combining ability, but the experiment gives no information on specific combining ability. The heritability estimates suggest that slow gains could be made in the host's ability to retard spread of the pathogen by a selection program.

The variation in canker length associated with inoculum sources reflects real differences and appears to be a predictable response of the host to each inoculum (table 5). Apparently the Michigan and Tully inocula exhibit greater virulence than the other two pathogen sources. The four inocula rank from most virulent Michigan, Tully next, Baldwinsville third, and Heiberg the least virulent (table 4). The repeatability of their levels of virulence suggests that the differences are genetic. No information is available on the genetic control system.

Again, pathogen virulence is not related to resistance heritability. The Michigan inoculum exhibits the greatest virulence and results in cankers with considerable variation in size, but the heritability estimate for canker length is the smallest. Most of the variation occurs in the males within females sources of variation, with a smaller part due to females. This, combined with the large within families mean square, is the cause of the low heritability value.

As in the case of callous formation and branch death, the largest heritability for canker length ($h^2 = 0.254$) was obtained with the Tully inoculum. The most plausible explantation for the greater predictability probably is the genetic uniformity of this inoculum, which was derived from a single ascospore. The other three inocula, in contrast, were derived from mycelia extracted from diseased bark. Greater variation could occur in each of these cultures because not only could a heterokaryotic condition be present with nuclei of two or more origins, but two or more genetically different mycelia originating from multiple infections are also possible. If the pathogen as well as the host varies, the predictability of the host response would be less and heritability low. If this hypothesis is correct, the heritability estimates from the Tully data would most clearly reflect the host's ability to respond to the pathogen and would be the most reliable estimates of the predictability of the host responses. Further experiments are planned to test this hypothesis. If this is correct, one would expect more rapid improvement in resistance than our results suggest now.

The slow spread of the disease in the host is frequently referred to as a tolerance reaction of the host. If slow enough, the pathogen presumably could persist for years in a rapidly growing tree without killing the host because trees die when their stems are girdled. Selection for tolerant genotypes is feasible in an aspen breeding program, and is highly desirable because this mode of resistance would not exert strong selection pressure on the pathogen for more virulent forms. This might be especially useful in breeding trees for short rotation croppings (Einspahr 1972).

The tolerance reaction depends upon a slow growth of the fungus whereas fast canker growth is required in the branch death response because the branch has to be killed before the fungus can reach the main stem. Therefore, the characters would be expected to be negatively correlated: groups with short cankers should exhibit a low frequency of branch death, and vice versa. A comparison of mean canker length and incidence of branch death in maternal half-sib groups (tables 3 and 4), however, does not reveal any obvious relations. Rank correlations (Snedecor 1946) were also calculated, based upon maternal half-sib group means and the rank of the 24 families. Though negative correlation coefficients were obtained for the Baldwinsville and Tully results for maternal half-sib group means for the Baldwinsville, Tully, and Michigan results for the family data, none of the correlations are statistically significant. If a negative relation does exist, it may have been obscured by the effect of branch diameter (at the site of the inoculation) on the earliness of branch death. This will be taken into consideration in future studies to test this hypothesis.

Although this study considered only three mechanisms of resistance, there are undoubtedly more. Artificial inoculations with a mass of mycelial inoculum precludes genetic evaluation of resistance mechanisms affecting spore germination and initial infection. Future studies will

attempt to determine the genetic control of resistance to natúral infections and the correlation of these results with that from artificial inoculations.

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NUCLEAR PROTEINS OF DRY AND GERMINATING CONIFER SEEDS

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ABSTRACT.--The proteins of the nuclear sap, the histones, and the nonhistone chromosomal proteins (NHCP) were extracted from a number of dry and germinating seeds and their composition was examined by polyacrylamide gel electrophoresis. The nuclear fraction was isolated and washed extensively with several buffer mixtures. The chromosomal material was then solubilized in a high salt-high urea buffer. After removal of the DNA by ultra-centrifugation, the chromosomal proteins were passed through a QAE-Sephadex column to separate the histones from the NHCP. Gel patterns of the NHCP varied quantitatively during the early germination of jack pine and minor qualitative differences in protein complement were also detected. Differences in the profiles of the NHCP were found among species of the Pinaceae. Histones from coniferous seeds compared favorably with pea histones in classification and electrophoretic mobilities. The changes in histones in profiles from different species and with different stages of germination were due mainly to the heterogeneous FI fraction. The methods are suitable for studies of nuclear protein metabolism and genetic regulation and expression in tree improvement programs. Biochemical techniques for extracting and characterizing nuclear proteins are summarized.

The control of transcription (suppression or induction of selected genes) is now being pursued by many scientists. The structure and function of the nuclear proteins are important in this control, and polyacrylamide gel electrophoresis of proteins can become a useful diagnostic tool when dealing with quantitative and qualitative changes in genetic expression. For example, Bekhor et al. (1974a) suggested that the nonhistone chromosomal proteins (NHCP) could be fingerprinted to study chromosomal aberrations once functions are assigned to each of these proteins.

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In this report we summarize methods to extract and characterize the nuclear proteins and present the known biological functions of proteins, especially those dealing with genetic expression. It is hoped that this study will eventually lead to methods to predict genetic expression (i.e., before it can be expressed visually) and to improve the genetic quality of conifers.

METHODS

Extracting and Characterizing Conifer Nuclear Proteins

To study the nuclear proteins in tissue, species specificity, and gene regulation, the extracted proteins should be pure, intact, and free from aggregation. We selected and modified methods to obtain high yields for extracting nuclear proteins. We avoided the use of denaturants, increased the rapidity of extraction, inhibited degradative enzymes, avoided contamination, and retained as much of the biological activity of these proteins as possible. Because nuclear proteins from storage tissues are especially difficult to purify (Bonner et al. 1968a, Grellet and Guitton 1973, Pitel and Durzan 1974), various combinations and extensions of the existing methodology were tried.

Numerous reports indicate the presence of protease in chromatin preparations and in the cytoplasm which can degrade histones (Paik and Lee 1970, Kincade and Cole 1966). Selective tissue-specific proteases confuse the estimates of qualitative and quantitative differences in composition (Hnilica 1972). Several protease inhibitors decrease the activity of these enzymes. These include 0.05M sodium bisulfite (Panyim et al. 1971), diisopropyl fluorophosphate (Hnilica 1972), $CdSO_4$ (Vaughan and Comings 1973), and phenylmethylsulfonyl fluoride (Wintersberger et al. 1973, Towill and Noodén 1973).

With the conifers we routinely used sodium bisulfite as a protease inhibitor. This was found to be especially needed for the germinating seeds. However, sodium bisulfite should be used with caution because base (pyrimidine) modification of chromatin RNA may occur. In some cells it may reduce the yield of nuclei and chromatin (Towill and Noodén 1973). To further decrease the activity of nucleases and proteases the buffers were at pH 8.0 (Jockusch and Walker 1974). The reagents we used were of the highest purity and were made fresh to prevent changes in the buffers that could affect the properties of the extracted proteins. For example, aged urea solutions form cyanate that could then react with amino acid sulfhydryl groups of proteins (Graziano and Huang 1971).

To prevent aggregation of the histone F3 molecules, 2-mercaptoethanol was included in the buffer during electrophoresis. Mercaptoethanol is also useful in reducing the binding of the histones to the NHCP (Levy et al. 1972).

EDTA, which can lead to losses of the arginine-rich histones (Stein and Borun 1972), was not needed nor used.

Chemicals that could irreversibly denature the proteins were avoided. Acid treatment to extract the histones from nuclei or chromatin before NHCP separation affects the structural properties of the NHCP (Graziano and Huang 1971). Phenol has been used to extract the nonhistone proteins (Teng et al. 1971); however, this reagent can irreversibly affect the native structure in some of the NHCP. Studies by Mischke and Ward (1975) showed that acid treatment or phenol changed the position of some of the NHCP during electrophoresis. Ionic detergents bind strongly to proteins and thus are not useful except for electrophoretic studies (Shirey and Huang 1969).

To help the dispersal of extra-nuclear material, without damaging the nuclei, Triton X-100 (nonionic detergent) was added at low concentrations (0.2 to 0.5 percent) (Sadowski and Steiner 1968, Panyim et al. 1971). Higher concentrations break nuclei and may cause partial solubilization and loss of nuclear proteins (D'Allesio and Trim 1968). Lower concentrations remove the outer nuclear membrane.

We used sodium deoxychloate (bile-salt anion) to remove cytoplasmic contaminants. It has detergentlike properties and solubilizes many subcellular components (Hadler et al. 1971) including the outer nuclear membrane (Monahan and Hall 1973). Low concentrations of about 0.001 M are needed because concentrations in the range 0.005 to 0.1 M can selectively extract the histones (Smart and Bonner 1971a, 1971b) and higher concentrations can cause partial lysis of nuclei.

The nuclear preparation should be washed with buffered media to remove contaminating proteins originating from the nuclear sap and cytoplasmic proteins that become adsorbed during isolation to the nuclei and chromatin. Generally, washing is done with buffered isotonic (0.14M) saline and with varying concentrations of Tris-HCl buffers. Jockusch and Walker (1974) found that increasing the ionic strength of the buffer from 0.001M to 0.01M Tris increased the amount of NHCP extracted. Huang and Huang (1969) decreased the ionic strength at pH 8.0 during purification of their nuclear preparation. Stronger saline (0.3M) improved the removal of cytoplasmic contaminants but losses of NHCP can still occur (Hnilica 1972). At saline concentrations of 0.35M, some NHCP are extracted together with cytoplasmic proteins (Comings and Tack 1973). Kostraba et al. (1975) found that the 0.35M NaCl wash contained proteins similar to the cytoplasmic and nuclear sap proteins. This fraction included loosely bound NHCP that, after four washings, contained 43 percent of the total NHCP. Goodwin and Johns (1973) reported a possibility of some histone degradation products in the 0.35M NaCl extract. At higher salt concentrations more NHCP is removed; e.g., at 2.0M NaCl, 81 percent is extracted.

We also used, with varying degress of success, extractions at low pH for the removal of cytoplasmic-contaminating proteins. Dick (1968) used pH 2.8 for purification of the histone fraction. We also included citric acid at 0.01M (pH 2.6) and aqueous ethanol.

The ratio of the nucleus to the cytoplasm is important. If this ratio is as low as 1:500 by volume there are greater chances of contamination (Evans and Ozaki 1973). Most methods use dense sucrose for purification of the chromatin preparations. The chromatin can be centrifuged through 1.7M homogeneous sucrose or through discontinuous sucrose (Bonner et al. 1968a, 1968b; Panyim et al. 1970). In our studies with conifer seed tissue, we repeated this process to ensure greater removal of the contaminants. In addition to sucrose purification, prolonged stirring of the crude chromatin in Tris-CHl buffers solubilizes some contaminating material (Bonner et al. 1968a).

To avoid denaturing conditions for the extraction of the chromatin proteins, we separated them by dissociating the nuclear preparation in a high salt-high urea buffer. Essentially all chromatin proteins can be separated from DNA by dissociation in a 2.0M NaCl-5.0M urea buffer (Bekhor et al. 1974a, 1974b; Kleinman and Huang 1972). DNA can be removed by centrifugation for 18 hr at 60,000 RPM, by column chromatography (such as Bio-Gel A-50 as described by Graziano and Huang 1971), or if desired, by denaturing conditions such as selective hydrolysis, by partitioning with phenol (Shelton and Neelin 1971), or with DNase. In our studies we used ultracentrifugation to remove the DNA followed by separation of the histones from the NHCP with QAE-Sephadex. The use of ion-exchange to separate these two classes of proteins has resulted in preparations with less than 1 percent cross-contamination between the two (Levy et al. 1972). One can also use columns of Bio-Rex 70 (Levy et al. 1972), SP-Sephadex C-25 (Graziano and Huang 1971), hydroxylapatite in high salt and urea (MacGillivray and Rickwood 1974), and electrophoresis on SDS (sodium dodecyl sulfate). Our studies with SDS electrophoresis showed negligible contamination of the histones and NHCP with each other. If needed, 2 percent SDS can be used to solubilize the chromatin components.

Numerous other combinations can be used for solubilization such as 6M Urea-0.4M GuCl (Levy et al. 1972), urea alone (Mischke and Ward 1975, Pitel and Durzan 1974), 1M$CaCl_2$ (Mohberg and Rusch 1969), and NaCl alone (Busch 1968, Wang 1967). However, several reports have shown that not all NHCP are removed with 2.0M NaCl (Levy et al. 1972, Kostraba et al. 1975). In the latter study, 19 percent of the NHCP could not be removed from DNA with 2.0M NaCl (buffered). Most of these proteins were released with 3M NaCl-7M urea. A method using cations to condense the chromatin was found better than the use of 2M NaCl (Flavell and Kemble 1974). The latter had more contaminating RNA. Methods using shearing of the chromatin help in further dissociation (Levy et al. 1972).

Numerous methods selectively extract the histones from nuclear preparations. Variations occur in pH (Hnilica 1972); sodium deoxycholate (Smart and Bonner 1971a); SDS; mixtures of urea, NaCl, and ethanol (Bolund and Johns 1973); various salt concentrations (Hnilica 1972, Bolund and Johns 1973); removal of F1 with 5 percent TCA or perchloric acid, ethanolic-HCl; tRNA and double-stranded DNA (Ilyin et al. 1972), and others. The use of urea in combination with NaCl appears to be a superior method for both dissolution of the chromosomal proteins and for retention of their biological functions.

Nuclear proteins from storage tissues are hard to purify. Fambrough et al. (1968) found significant amounts of contaminants in histone preparation from pea cotyledons. These had low electrophoretic mobility and were said to be acidic ribosomal proteins and NHCP. Histones can be contaminated by proteins from the mitochondria and nucleoli (Mohberg and Rusch 1970). Histones prepared by acid or salt dissociation may have small quantities of ribo- and deoxyribonucleotides (Greenaway and Murray 1973). Direct acid extraction of the nuclei or chromatin to obtain the histones may result in some contamination by the NHCP (Sadgopal and Bonner 1970a, 1970b; Wilhelm et al. 1971). High molecular weight NHCP have been reported to contaminate certain histone preparations (Levy et al. 1972, Graziano and Huang 1971).

The extracted NHCP fraction can be contaminated from several sources. For example, Goodwin and Johns (1972; 1973) and Johns and Forrester (1969) found contamination of the NHCP by the nonspecific adsorption of cytoplasmic and nuclear sap proteins to the chromatin during isolation. Hill et al. (1971) said that the NHCP may be in equilibrium with the soluble nuclear sap proteins under physiological conditions, e.g., NHCP turnover. It was difficult to determine precisely what belonged to the NHCP or to the nuclear sap. The NHCP were also found to be contaminated by the acidic nuclear membrane proteins (Harlow et al. 1972) to the extent of 11 percent (Suria and Liew 1974).

By considering these observations and introducing the modifications for coniferous tissues we have prepared the nuclear and cytoplasmic proteins in figures 1 to 4.

RESULTS AND DISCUSSION

Our results show that the nuclear proteins (histones, NHCP, and nuclear sap proteins) can be extracted from conifers and characterized by polyacrylamide gel electrophoresis. The purity and resolution of these proteins are comparable to those described for other plants and animals.

Problems of identification of proteins often arise by contamination, degradation, selective extraction, and aggregation. Some of these proteins may be in equilibrium with each other (e.g., NHCP and nuclear sap proteins) and thus may be hard to define precisely as belonging to one class or

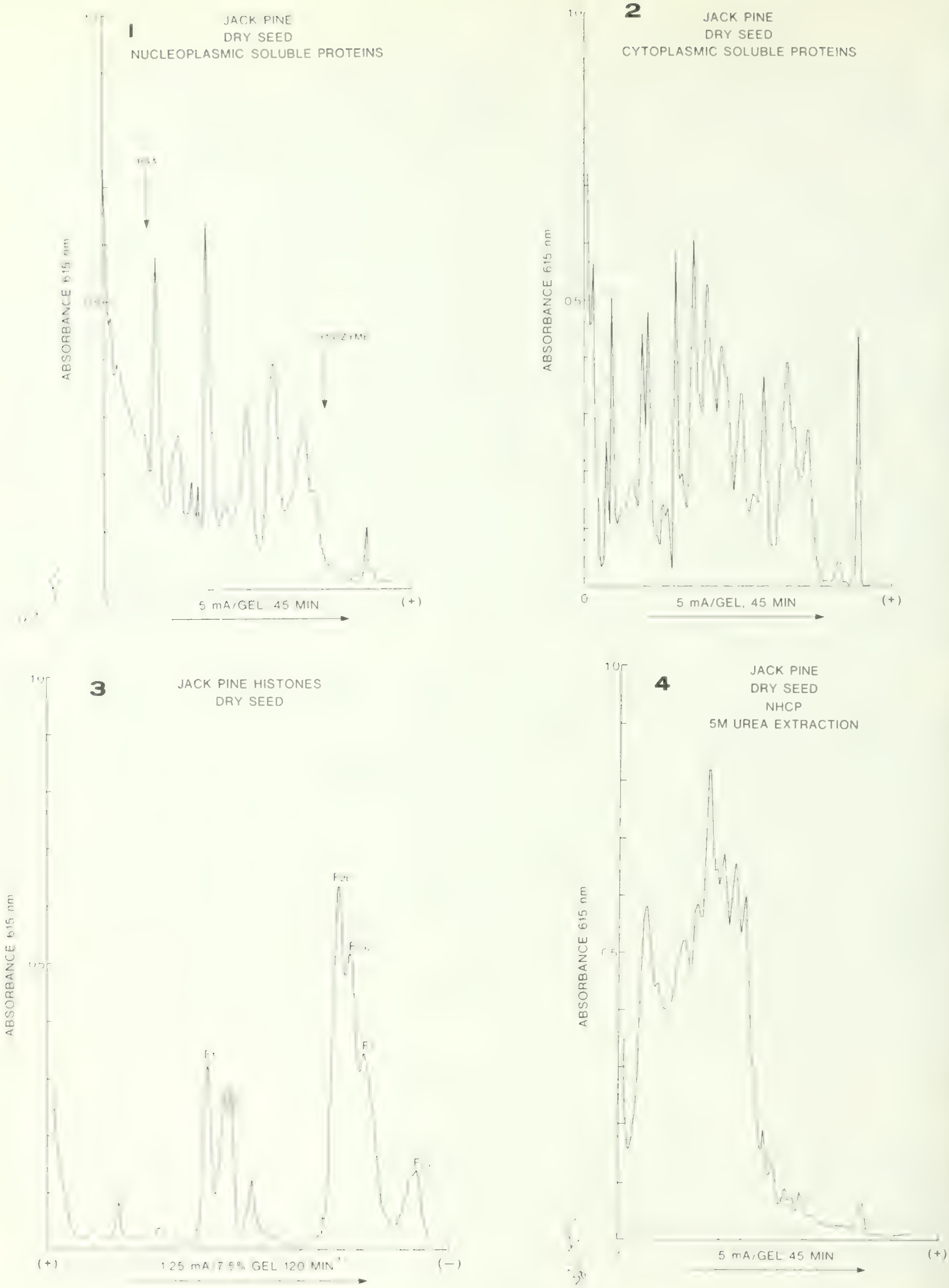

Fig. 1-4. Protein characterization of dry jack pine seed.

another. Also some can be transported between the cytoplasm and nucleus (Stein and Borun 1972). In our studies we examined the proteins of the cytoplasm, nucleoplasm, and the chromosomes and first compared them with each other to more precisely show that most belonged to separate classes and can be separated as such.

The cytoplasmic and nucleoplasmic soluble proteins had characteristic electrophoretic profiles that were significantly different from each other (figures 1 and 2). Differences in composition were found during germination (dry seed vs. 48 hr) for some of the bands for each of the classes. Studies with the cytoplasmic proteins, besides being useful to determine contamination with the different classes of proteins, are important because some of them may be gene regulators (Vaughan and Comings 1973), and may be able to bind to DNA (Choe and Rose 1974).

With jack pine we found that the soluble nuclear proteins were markedly different from those of the corresponding chromatin NHCP, although the two patterns showed some similar bands (figures 1 and 4). Similar results were found by others (Comings and Tack 1973, MacGillivray and Rickwood 1974). Also, the nuclear sap proteins can bind to DNA (Vaughan and Comings 1973) and may have some gene regulatory function (Comings and Tack 1973).

Histones were extracted from various stages of germination of jack pine and found to vary quantitatively after 24 hours of germination (fig. 3). The profiles for the dry seed and for 12 hrs imbibed seed were identical. DNA synthesis is difficult to detect during early stages of germination (Pitel and Durzan 1975). Because histone synthesis is associated with DNA synthesis (Hnilica 1972), the lack of any major change in the histone profile is consistent with previous results. Changes in the histone fraction after 24 hrs imbibition were due mainly to the very lysine-rich (F1) fraction. The protease inhibitor, sodium bisulfite, was especially useful for the germinated seeds. Extraction of 4-day-old seeds in the absence of sodium bisulfite gave a 50 percent reduction in the content of the F1 histone and produced several additional bands in the F1 region and gave one band with a mobility between F3 and F2a1.

Examination of the histones from several members of the Pinaceae revealed very little species specificity.

After passage of the conifer chromatin, soluble in 3M NaCl-5M urea, through a QAE-Sephadex column, the histone and NHCP fractions were analyzed by SDS electrophoresis and found to be essentially free of contamination from each other. By contrast, direct acid extraction of the nuclear preparation for histones gave numerous contaminating bands that could include proteins of the ribosomes (Mohberg and Rusch 1970, Fambrough _et al._ 1968) and NHCP (Graziano and Huang 1971, Grellet and Guitton 1973).

The NHCP were extracted using different concentrations of NaCl, various combinations of urea and NaCl, and urea alone. Profiles from all cases were largely similar on a qualitative basis. Most differences were found with the 0.14M NaCl. This extraction only removes 10 to 15 percent NHCP and is used mainly for removing nuclear sap proteins from the nuclei. Although this extraction contains the normal population of NHCP it also has proteins that resemble those from the nucleoplasm.

We compared the NHCP profile from dry jack pine seeds, where the chromatin is repressed, to that of the 48 hrs imbibed seed where gene activity was substantially greater. The major bands varied quantitatively. Unique bands were found with the minor proteins in germinated seeds. Although Coomassie Brilliant Blue was used for some studies it was not used to compare quantitative differences as the dye deviates from Beer's Law at higher protein concentrations (Chrambach et al. 1967). Caution must also be used with Amido Black, as it stains metachromatically (Johns 1967).

Limited species specificity was found when comparing the NHCP profiles of several Pinus spp. More qualitative and quantitative differences were found when comparing the Pinus spp. with those from Abies or Picea. The further interpretation of these results from a genetic and physiological viewpoint is in progress.

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THE POTENTIAL FOR CLONING
WHITE SPRUCE VIA TISSUE CULTURE

Robert A. Campbell and Donald J. Durzan[1]

ABSTRACT.-- When hypocotyl segments of white spruce were placed with their apical ends in an agar medium containing 10^{-5} M 1-naphthaleneacetic acid (NAA) but no 6-benzylaminopurine (BAP), 50 percent formed roots. Almost all segments placed with their basal end in a medium containing 10^{-5} M BAP with 10^{-7} M NAA formed scalelike organs. When explants with the scalelike organs were transferred to media containing neither BAP nor NAA, the organs grew into needles, buds developed, and elongated, branched shoots were obtained from these buds. A number of shoots have been obtained from a single hypocotyl segment. One such shoot has rooted. These results strengthen the hypothesis that a small explant could be used to mass propagate a superior tree.

There will probably be a massive shortage of wood in the world market within 20-25 years (Keays 1974)[2,3] For this reason there is an urgent need to increase the productivity of our forests.

One means of doing this is by reforesting with superior genotypes that grow faster, larger, straighter, are responsive to silvicultural practices, and are resistant to diseases and pests. The question is, "How to get the superior genotypic material for planting?"

One way is through breeding, as has been done successfully for many agricultural crops. Unfortunately, the long life cycle of trees makes obtaining superior varieties a lengthy process. In Ontario, 30 million white spruce seedlings are outplanted each year but only 10 percent are from seed collected in seed orchards and production areas. Because the

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[3] Jones, P. 1975. Address to the Canadian Pulp and Paper Association, Montreal. March 25.

trees in the present orchards are not the progeny of controlled breeding programs and have not been tested, the genetic gain in using seed from them is probably small. Thus it will be some time before genetically improved and proven trees are available in sufficient numbers and are mature enough to produce useful quantities of improved seed.

Another way to reforest with superior genotypes is to take advantage of the variation in the natural population and vegetatively propagate superior specimens. This could allow immediate productivity gains. The problem here is that by the time a tree is old enough to demonstrate that it is superior, it is difficult to propagate it vegetatively by rooting cuttings. As the age of the ortet of spruce increases beyond 10 years, rooting ability decreases rapidly. "Percent rooting, speed of rooting, root length and number, survival, and growth in and after the year of rooting, all decrease with increasing age of the parent tree" (Girouard 1974). Another problem is that rooted lateral shoots must undergo a transition from plagiotropic to orthotropic growth and this occurs less readily with increasing ortet age (Girouard 1974). A final problem is that cuttings may grow slower than seedlings. For the first 5 years at least, the stem volume growth of _Pinus radiata_ cuttings was considerably less than that of seedlings (Sweet and Wells 1974, Shelbourne and Thulin 1974, Libby 1974). If these differences continue beyond 5 years, they are probably associated with meristem aging. This could cancel out gains expected from the use of cuttings rather than seedlings from superior genotypes.

In an attempt to bypass some of the problems mentioned above, we have been investigating the use of tissue culture for the vegetative propagation of forest tree species.

Having obtained suitable media for the continuous culture of callus and suspensions of white spruce, jack pine, and American elm, we have recently begun attempts to induce differentiation in our cultures. The present work utilizes aseptic hypocotyl segments from 6 to 12-day-old white spruce seedlings (fig. 1). This is a model system because practical application would require the use of tissue from trees old enough to have demonstrated superior qualities. But the model system is useful at this stage for several reasons: (1) it is easier to obtain large numbers of sterile explants by surface-sterilizing seeds and then germinating them aseptically than it is to sterilize tissue from trees in the field; (2) there are no seasonal variations in the starting material because seeds can be germinated in a growth chamber any time; and (3) tissue from juvenile plants is often easier to induce to differentiate, so it makes more sense to start here and proceed to the more difficult later.

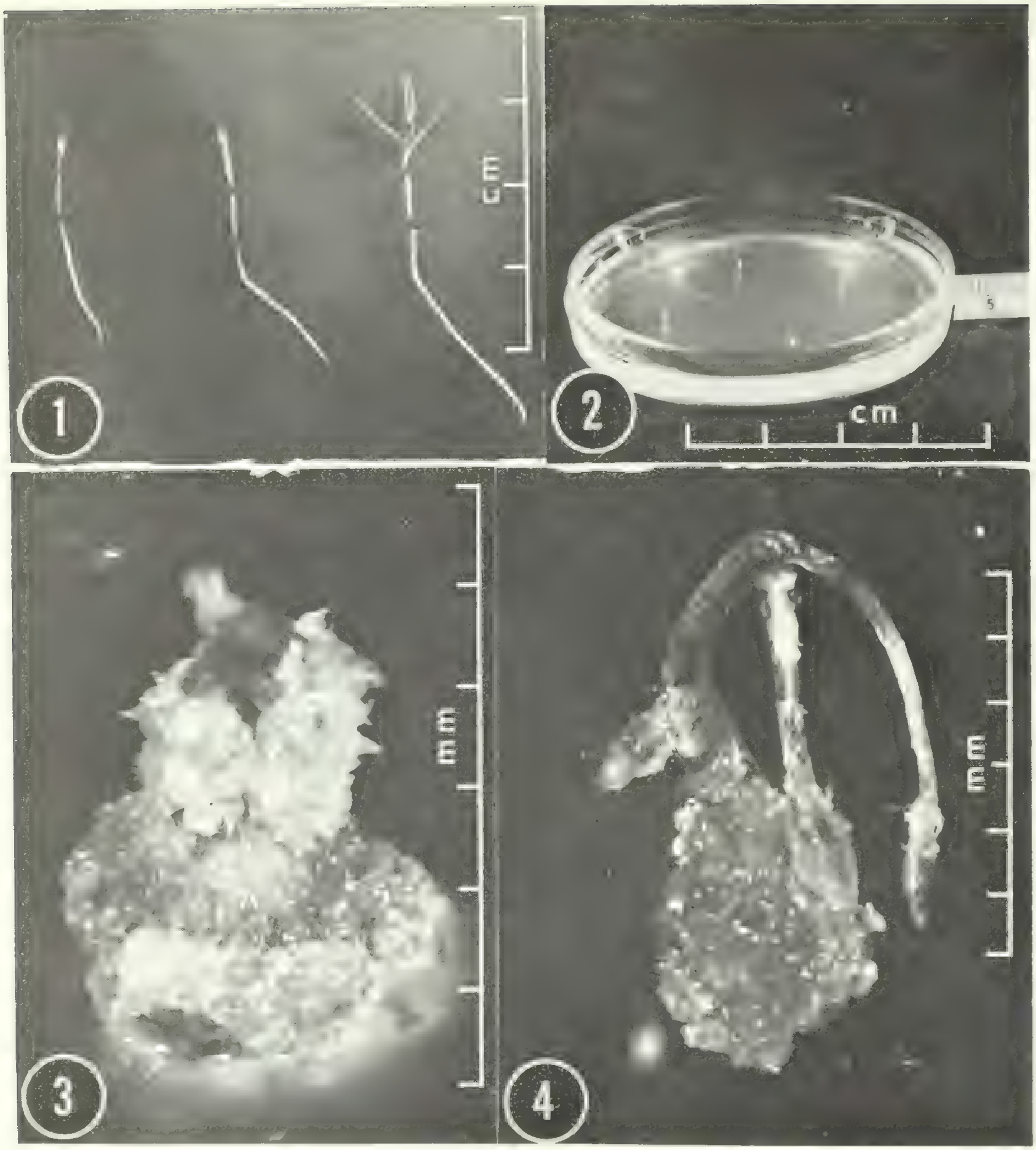

Figure 1.--Six to 12-day-old white spruce seedlings. A 5 to 7 mm segment of hypocotyl has been excised from each seedling taking care to exclude the apical meristem.

Figure 2.--Hypocotyl segments with one end embedded in agar medium in culture dish.

Figure 3.--Hypocotyl segment after incubation on a medium containing a high level of BAP and low NAA. There is a basal callused region in contact with the agar medium, a swollen intermediate region covered with scalelike organs, and an unswollen tip. There has been little longitudinal growth.

Figure 4.--Hypocotyl segment after incubation on a medium containing a low level of BAP and a high level of NAA. There is a basal callused region and above this a portion of unchanged hypocotyl bearing three roots. There has been considerable elongation of the explant (cf figure 3).

METHODS AND RESULTS

Detailed methods and media have been reported elsewhere (Campbell and Durzan 1975). Hypocotyl segments used were 5 to 7 mm long and were cut carefully to exclude the apical meristem (fig. 1). The segments were cultured in an agar medium in 50-mm petri dishes in a vertical position with the end formerly attached to the radicle embedded in the medium (fig. 2). The segments differentiated by expanding laterally but very little vertically (fig. 3). There is some callusing at the base, i.e., the portion in contact with the medium. Above this there is a portion that is swollen and has scalelike outgrowths and at the top there is an unswollen portion. The fact that the scalelike outgrowths are below the tip, together with the cutting procedure, demonstrates clearly that the outgrowths did not arise from a pre-existing apical meristem.

The key factor controlling this differentiation is the cytokinin-auxin balance (table 1). In this experiment, segments were cultured on media containing different amounts of the plant growth regulators 1-naphthaleneacetic acid (NAA) and 6-benzylaminopurine (BAP). The frequency of induction increased with increasing BAP and decreasing NAA concentration.

Table 1.--Explants that had produced at least one scalelike organ after 20 weeks in culture under varying conditions,[1] as a function of 1-naphthaleneacetic acid (NAA) and 6-benzylaminopurine (BAP) concentration in the medium[2]

(In percent)

BAP (M)	NAA (M) 10^{-5}	NAA (M) 10^{-7}	NAA (M) 0
10^{-5}	14	64	69
10^{-7}	0	0	0
0	0	0	0

1 13.5 hours light at 20°C and 10.5 hours of dark at 7°C.

2 The number of segments per treatment ranged from 11 to 17 (differences due to contamination losses).

The active range and different environmental conditions were examined in more detail in a further experiment (table 2). Induction occurred better and faster under constant than under varying conditions but by

98 days the number of explants that had produced organs had reached a maximum in both environmental conditions. The explants cultured under varying conditions were inhibited by the highest level of BAP whereas those under constant conditions could not be induced to develop further with subsequent treatments.

Table 2.--Explants that had produced at least one scalelike organ after 14 weeks in culture, as a function of NAA and BAP concentration in the medium[1]

(In percent)

	NAA (M)			
BAP (M)	10^{-5}	10^{-6}	10^{-7}	0
10^{-4}	25(13)[2]	78(38)	82(28)	89(19)
10^{-5}		75(50)	84(56)	86(58)
10^{-6}		45(22)	59(50)	53(38)

[1] The number of segments per treatment ranged from 20 to 36

[2] The figures in parenthesis were obtained under varying conditions (13.5 hours light at 20C and 10.5 hours dark at 7C). The figures not in parenthesis were obtained under constant light and temperature at 20C.

Those induced by lower levels of BAP did develop. Thus, the optimum induction occurs under constant environmental conditions with 10^{-5} M BAP and 10^{-7} M or OM NAA.

In the previous experiments, the explants were placed right side up. When they were inverted (i.e., the end formerly attached to the apical meristem was placed in the medium) organs were again induced at about the same frequency with the same BAP-NAA optima. The difference was that roots could also be induced (fig. 4, table 3). The requirement for root induction was high NAA and low BAP. This is opposite to that for induction of the scalelike organs and thus follows the pattern of differentiation control reported by Skoog and Miller (1957).

Having induced roots and scalelike organs, attempts were made to control further development. The roots did not develop much beyond that shown in figure 4 and eventually died, although a number of different media were tried. The scales did develop if the explants were left on the same media for a period or were transferred to a medium containing neither BAP nor NAA (this was probably the same treatment because the

growth regulators likely got depleted in the first instance). The scales became elongated and more needlelike (fig. 5). When explants at this stage were broken up and cultured for a further period on medium lacking NAA and BAP, numerous elongated shoots bearing normal-looking needles developed (fig. 6).

Table 3.--Explants that had produced at least one root after 12 weeks in culture, as a function of NAA and BAP concentration in the medium[1]

(In percent)

	NAA (M)		
BAP (M)	10^{-5}	10^{-7}	0
10^{-5}	15(19)[2]	0(0)	0(0)
10^{-7}	28(28)	0(0)	0(0)
0	47(25)	0(0)	0(0)

[1] The number of segments per treatment ranged from 25 to 36.

[2] The figures in parenthesis were obtained under varying conditions (13.5 hours light at 20C and 10.5 hours dark at 7C). The figures not in parenthesis were obtained under constant light and temperature at 20C.

All of the previous steps have been repeated and occur with a high frequency. The final step, the rooting of induced shoots to regenerate a whole plant, has only occurred recently so its frequency, control, and repeatability have not been fully determined. The shoot in figure 7 produced roots following shoot elongation on the medium lacking BAP and NAA. It has been transferred to a sand-sphagnum mixture in a pot and is thriving.

DISCUSSION

We have demonstrated that it is possible to regenerate whole white spruce plants from a small piece of tissue. Similar results have also been recently reported for longleaf pine (Sommer et al. 1975), Cryptomeria japonica (Isikawa 1974), and Douglas fir (Rediske 1975). Once the process has been optimized, the next step would be to attempt to repeat it with tissue from a mature tree. Because the shoots in the present work apparently arose from epidermal tissue (Campbell and Durzan 1975), a

Figure 5.--Hypocotyl segments after a prolonged incubation on a medium containing high BAP and low NAA. Depletion of the growth regulators in the medium has allowed the scalelike outgrowths to elongate.

Figure 6.--A number of shoots obtained by dividing up an explant, such as those in figure 5, and incubating the pieces on a medium lacking BAP and NAA.

Figure 7.--An explant bearing two induced shoots that have rooted (arrows).

logical tissue to try would be needles. Further justification for this choice comes from the fact that leaf epidermal tissue from mature herbaceous plants has been readily induced to form shoots (Tran Than Van and Drira 1971, Chlyah and Tran Than Van 1971). If each needle could produce 10 shoots and a single bud has 100 to 200 needles, the number of potential propagules from a single tree would be enormous. It should also be noted that because the plantlets induced from tissue cultures do not arise from pre-existing apical meristems, their apical meristems may be rejuvenated. Slow growth, plagiotropic growth, and poor rooting may not be a problem with such vegetative propagules.

A slightly different way of using tissue culture in propagation would be through suspension cultures. Tissue from many plant species can be grown in an agitated liquid medium as single cells and small clumps--much like bacteria. We have done this in our laboratory with white spruce, jack pine, and American elm. The doubling time of such cultures is less than a week, so a tremendous number of cells and clumps can be generated in a short time. For example, starting with 1 gram of tissue, 1 kilogram could be generated in 10 weeks and 1,000 kilograms in 20 weeks. With a number of plant species it has been possible to induce the free cells and clumps to form embryos that develop into normal plants capable of producing viable seed (Steward et al. 1964). The best studied example is carrot. If white spruce embryos could be induced in suspensions at the same rate as carrot embryos (Halperin 1967), then in only 100 liters of medium, 73 million plantlets could be produced and raised in containers for field planting. This is more than enough to plant 100,000 acres (the predicted rate of white spruce planting in Canada to 1985 at 8 by 8 spacing (Carlisle and Teich 1971).

Is this possible? We can grow spruce tissue as suspensions. A number of herbaceous species have been induced to form embryos in suspensions (Halperin 1967, Thomas and Street 1970). White spruce tissue cultures have been induced to regenerate whole plants. Cambia and vascular tissue have been induced in white spruce suspensions (Durzan et al. 1973). Thus, the probability is high that it is only a matter of time and effort to achieve effective vegetative propagation of spruce by tissue culture.

The predicted world wood shortage by the year 2000 makes it seem mandatory that all methods of increasing forest productivity be fully explored immediately. Through tree improvement and genetics, Canada will be able to increase the productivity of its forests and thus fulfill its responsibility to help minimize the predicted world wood shortage.

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THE CLONAL TEST: AN AID TO PROGENY TESTING AND A WAY TO SPEED UP GENETIC GAINS

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ABSTRACT.--Phenotypic measurements of loblolly pine (*Pinus taeda* L.) and Virginia pine (*Pinus virginiana* Mill.) were obtained from parent trees in wild stands, from ramets in clonal orchards, and from seedlings in control-pollinated progeny tests. Total tree height, stem diameter, crown form, bole straightness, and wood density were the characteristics assessed. The degree of resemblance between ortets and ramets, ramets and progeny, and parent trees and progeny was determined by estimating variances and heritabilities. Broad- and narrow-sense heritabilities were estimated from clonal and progeny populations. Ortet-clone, ortet-seedling, and clone-seedling regression and correlation analyses were used to measure the likeness between parent and progeny. These analyses revealed greater similarities between progeny and ramets than between progeny and mature parent trees in the forest indicating the possibility of improving the efficiency of selection through clonal testing. Calculations of expected genetic gains confirmed the importance of roguing inferior clones from the seed orchards as a step toward maximizing gain in a single generation. Clonal tests that can be converted into seed production orchards are recommended as aids to the more standard and expensive progeny tests and to speed up genetic gains both for Virginia and loblolly pines.

In Canada 300 million seedlings are produced annually in forest nurseries. With such a large program, even small genetic improvements in the planting stock will result in appreciable returns at time of harvest.

Selection of elite trees is the basis of a forest tree breeding program and much effort has been expended on this activity during the

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past 15 years. Tree breeders now recognize a large amount of variation in growth, form, and wood characteristics within most tree species. How much of this variation is caused by the genetic make-up of the tree and how much represents a response to the environment is a function of the degree of inheritance; this is usually expressed through the concept of heritability.

The demand for genetically improved trees is great, but the time and costs involved in setting up a tree improvement program to produce large quantities of genetically improved seed are important. The task involves tree selection, seed orchard establishment and maintenance, progeny testing, plus many more activities such as disease and insect control. In order to progeny test selected clones to determine their breeding value, a "tester" system is often adopted. However, despite the fact that clonal orchards produce seed early, it is difficult to obtain sufficient seeds of the crosses needed. The result is that after 5 or more years of effort, seeds of only a portion of the planned crosses may be available for the test. Because any delay in an applied program costs money, evaluations of the general combining ability of the clones must be based on an insufficient number of crosses, or tests must be delayed until all crosses are available. Therefore, a method that could reduce the costly procedure of progeny testing would be of great value to tree improvement programs.

Faster testing may be possible through the use of the resemblance between ortets[2/] and ramets,[3/] between ortets and seedling progeny or between ramets and progeny. A greater similarity between clones[4/] and seedling progeny than between ortets and seedling progeny would suggest the possibility of selection, using a clonal test in a clonal seed orchard or a clone bank; this would be more effective than selection based upon the parent tree in the forest. Clonal testing would be of value for preselection of suitable material for use in the breeding program and could reduce the cost of the very expensive progeny tests.

This paper reports the results of an investigation of the resemblances between ortets and grafts, grafts and seedling progeny, and between ortets and progeny of loblolly pine (*Pinus taeda* L.) and Virginia pine (*Pinus virginiana* Mill.) and suggests a technique to speed up genetic gains.

2/ The original plant from which a clone has been derived.

3/ An individual member of a clone.

4/ A group of genetically identical plants derived asexually from a single individual.

MATERIAL AND METHODS

Plant Material

Three distinct groups of genetically related material were used in the study: parent trees, grafts of the parents, and control-pollinated progeny. The loblolly pine population consisted of 20 mature trees growing in wild forest stands, grafted clones of first and second propagation, and 57 control-pollinated families of the clones. Loblolly pine ortet ages were between 29 and 75 years and averaged 52 years.

The Virginia pine population was composed of 21 parents, their 10-year-old grafts, and 105 progeny families obtained from the diallel mating [5/] of the clones. The complete failure of certain crosses or an insufficient number of seeds produced resulted in the reduced number of families available. In addition, the selfs were excluded from the study. The Virginia pine ortets averaged 23 years old, their age varied between 17 and 36 years. For both species progenies were 4 years old at the time of measurement.

Vigorous scions were collected in the lower portion of the ortet crowns and pot grafted on 2-year-old rootstocks. The first propagation clones were 9-years old at the time of the second propagation.

Measurements

Measurements of stem diameter were taken to the nearest 0.1 inch at breast height on the ortets, at 2.5 feet above the scion-rootstock union on grafts, and at 2.5 feet above the root collar on the seedlings.

Total heights of both parents and grafts were determined to the nearest foot using a Blumes-Leiss altimeter. The progeny heights were measured with a graded height pole.

Crown form and stem straightness were subjectively evaluated using a scoring system based on crown radius, crown density, uniformity, dominance of the main leader, and branch characteristics such as branch diameter and length, branch angle, and sinuosity. Trees with the best crown scored 6 and trees with the poorest scored 1. Subjective stem grading was similar using a 1 to 6 scale depending on the trees' stem straightness. In all instances measurements were taken on 10 ramets per clone and on a maximum of 60 seedlings per full-sib family.

Unextracted wood specific gravity was determined for wood samples obtained at breast height from each ortet using a 3/8-inch increment borer. In the orchards, three grafts per clone were chosen at random

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5/ Mating design resulting from the crossing of the parents in all possible combinations.

and a wood sample obtained at 2.5 feet above the graft union, also using the increment borer. In the progeny test, 2 trees per plot, for a maximum of 20 per full-sib family, were cut and a disk 2 inches thick was taken at 2.5 feet above the ground level.

Statistical Procedures

A general least squares analysis for a diallel experiment was done on the progeny population (Schaffer and Usanis 1969). A nested analysis of variance assuming a random model was used to separate the genetic and environmental sources of variation from the clonal population.

Narrow-sense heritabilities were estimated using the formula appropriate to the diallel mating:

$$h^2 = \frac{4\sigma^2_{gca}}{\sigma^2_{gca} + \sigma^2_{sca} + \sigma^2_{b} + \sigma^2_{\omega}}$$

where h^2 = narrow sense heritability,

σ^2_{gca} = variance due to difference in general combining ability,

σ^2_{sca} = variance due to difference in specific combining ability,

σ^2_{b} = plot to plot variance, and

σ^2_{ω} = within plot variance.

Broad-sense heritability was calculated as the ratio of the among clone variance to the total variance and may be presented as follows:

$$H = \frac{\sigma^2_c}{\sigma^2_c + \sigma^2_r}$$

where: H = broad sense heritability,

σ^2_c = among clone variance, and

σ^2_r = within clone variance.

Heritability estimates have also been calculated from the regression of progeny on ortet and on the grafted clone. The appropriate formula is:

$$b = \frac{\mathrm{Cov}\ (O\text{-}P)}{\sigma_p^2} = \tfrac{1}{2}\, h^2$$

where: b = regression coefficient of progeny on parent,

Cov (O-P) = covariance of progeny mean on one parent,

σ_p^2 = phenotypic variance of parent, and

h^2 = narrow-sense heritability.

To assess the reliability of the heritability estimates, standard errors of the variance components were calculated using the equation given by Anderson and Bancroft (1952) and by Falconer (1960) (Corriveau 1974).

RESULTS

Nested analyses of variance of clonal populations revealed highly significant genetic differences among clones for all characteristics studied. Results obtained from first and second propagation grafts of loblolly pine indicated that cloning effects[6/] (topophytic and cyclophytic effects) biased estimates of total genetic variance upward for growth but had little effect on variances in the cases of stem straightness and crown form (table 1). Differences among ramets of the same clones are less than among clones because they share the same genotype as well as a common nongenetic component caused by physiological and morphological properties of the mother tree. When scions or cuttings are taken from ramets adapted to different micro-environments, this common nongenetic component may be partially or totally lost. Two-stage cloning has been proposed by Libby and Jund (1962) to reduce cloning effects. Virginia pine clone height and diameter were negatively correlated with ortet age ($r = -0.62^{**}$ and -0.56^{**}, respectively), reflecting strong cyclophytic effects. Environmental components were found to be less affected and broad-sense heritability values were less biased due to the presence of the confounded cloning component in both the numerator and denominator of the variance ratios.

Mean clone repeatabilities were moderate to strong. Due to large environmental variances, broad-sense heritabilities were smaller than were the repeatabilities (table 2).

6/ Combined effects of the scion position within the crown and of ortet age on the vegetative and reproductive development of the ramet.

Table 1.--Genotypic and environmental variance estimates of loblolly and Virginia pine height, diameter, stem straightness, and crown form from grafted clones 1/

Characteristic	Among clones (σ_c^2) 2/			Within clones (σ_r^2) 3/		
	Loblolly		Virginia	Loblolly		Virginia
	First propagation	Second propagation	First propagation	First propagation	Second propagation	First propagation
Height	4.631±1.772	1.108±.653	4.782±2.263	9.638	9.333	26.705
Diameter	.795± .324	.494±.486	.091± .470	2.263	10.348	.649
Crown form	.426± .173	.496±.190	.376± .147	1.209	1.040	1.022
Straightness	.135± .038	.225±.102	.446± .165	.660	.954	1.010

1/ Variances are based on 10 ramets per clone.

2/ σ_c^2 = Among clone variance = total genetic variance plus a component due to cloning effects.

3/ σ_r^2 = Within clone variance = environmental variance.

Table 2.--Comparison of heritability estimates by variance components, regression, and correlation analysis

Characteristic	Clonal population 1/		Progeny population 2/		Regression 3/		Correlation 4/	
	R_r	R_c	Family	Individual	Progeny-ortet	Progeny-clone	Ortet-progeny	Clone-progeny
LOBLOLLY PINE								
Height	0.32	0.83	0.15	0.05	0.01	0.08	0.01	0.04
Diameter	.26	.78	--	--	--	--	--	--
Crown form	.26	.78	.23	.07	.02	.16	.01	.14
Straightness	.17	.67	.37	.13	.08	.25	.04	.04
VIRGINIA PINE								
M.A.H.B. 5/	0.15	0.64	0.33	0.13	0.12	0.22	0.14	0.22
M.A.D.G.	.12	.58	.15	.06	.09	.12	.09	.08
Height	.15	.64	.33	.13	.04	.12	.01	.22
Diameter	.12	.58	.15	.06	.01	.04	.01	.15
Crown form	.27	.79	.43	.10	.04	.08	.09	.16
Straightness	.31	.82	.37	.10	.08	.06	.01	.12
Specific gravity	.77	.91	.47	.38	.53	.25	.24	.27

1/ R_r = repeatability of grafts of a clone or broad-sense heritability.
R_c = repeatability of a clone mean

2/ Family = family mean heritability, individual = individual heritability or narrow-sense heritability.

3/ Heritability estimates for loblolly pine are from the regression of seedling progeny on the female parent.

4/ Heritabilities obtained by the correlation of single parent and progeny and adjusted for the number of siblings per family (Franklin 1973).

5/ M.A.H.G. = mean annual height growth, M.A.D.G. = mean annual diameter growth.

In most instances, variance component analyses done on progeny data indicated statistically significant differences in general combining ability. Specific combining ability was an important source of genetic variation for growth characteristics while additive genetic variance was of prime importance in explaining genetic differences in crown form, straightness, and wood density. The same analyses also indicated that heritability values and efficiency of selection for advanced generations could be increased by the reduction of the environmental variance through careful planning of the field design.

Before progeny tests are available, clonal material is sometimes used to obtain estimates of heritability and to calculate expected genetic gains from selection and breeding. Results from analyses of clones and seedling progeny indicate that broad-sense heritabilities may be used with confidence as the upper limit for narrow-sense heritabilities. However, due to the variable importance of the first and second order genetic interaction from one characteristic to another, it would be unsafe to use a constant portion of the broad-sense heritabilities for any trait when calculating expected genetic gain. Too large or too small gains could be predicted leading to the acceptance or rejection of specific breeding programs. Narrow-sense heritabilities were 30 to 85 percent of the broad-sense heritabilities depending on the character involved (table 2).

Narrow-sense heritabilities calculated for growth and form characteristics from the regression of progeny on mature parent trees (table 2) were generally low and unreliable, reflecting the difficulty of predicting offspring juvenile performance on the basis of parental phenotypic measurement alone and vice versa. When growth of the parent trees are significantly correlated with age differences, the genotypic differences are partially or totally masked. Adjustments made to a common parental age were useful in revealing the presence of additive gene effects on the expression of the characters. The estimates obtained from the regression of seedling progeny on clonal parents were more precise and compared favorably to estimates obtained by variance analyses (table 2).

Correlations were also used to measure the degree of resemblance between ortet and graft, ortet and progeny, and between graft and progeny. Significant relations were found between mean annual growth of Virginia pine ortets and grafted clones ($r = 0.63^{**}$ for height and 0.52^{**} for diameter) and between clonal parents and seedling progeny ($r = 0.43^{**}$ for height and $r = 0.48^{*}$ for wood density). A significant correlation was also found between specific gravity of parent trees and their seedlings ($r = 0.45^{*}$). The correlation coefficient between parent and progeny is often preferred to the regression coefficient as an estimate of the heritability when large scale measurement differences exist between the relatives due to important age or environmental differences. Uncorrected heritabilities obtained by correlation

were larger than estimates obtained by regression and variance analyses. When adjustments were made for the number and degree of relation among members of a single family (Falconer 1960), the heritabilities were of the same magnitude as those calculated by regression analysis (table 2). However, correlation and regression methods can give exactly the same estimates only when the parent and progeny variances are equal.

DISCUSSION

Progeny testing is costly in time and effort. Even with a simple testing system, and despite the fact that clonal material reproduces early, complications still occur. Sometimes, after 5 or more years of effort, only a portion of the crosses necessary to obtain the required genetic information are available. An additional 5-year period is also required before reliable data can be obtained from the progeny tests for roguing. During the waiting period, seeds produced are improved by only one selection cycle. The longer the waiting period, the greater the proportional loss.

Greater similarities between progeny and clonal parent than between progeny and mature parent tree make possible the utilization of clonal testing as a tool to increase and speed up genetic gains through the roguing of seed orchards. Calculations have shown roguing[7] of the inferior clones in a seed orchard to be an important step toward maximizing gains in a single generation. Predicted genetic gains following two cycles of selection in loblolly and Virginia pine populations are presented in table 3. A 1 percent selection intensity was assumed for wild forest stands during the first cycle of selection. The second cycle represents the roguing of 50 or 70 percent of the clones in the seed orchard on the basis of either progeny testing or clonal testing. Results indicate that roguing of the loblolly pine orchard on the basis of the clones' own performance would result in substantially higher gains than roguing on the basis of the clones' 4-year-old progeny performance. More important gains are also predicted for Virginia pine height and diameter following roguing on the basis of clonal performance than on the basis of progeny performance.

Clonal testing has the advantage of not requiring time beyond the 5 or 6 years after clonal establishment. Clonal testing is a method of testing where the co-ancestry coefficient between parent and progeny (as well as among progeny of the same parent) is equal to one, and thus offers more reliable genetic information than any other type of relatives. However, clone performance includes effects due to cyclophysis and topophysis, which may give false information. To obtain

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7/ Systematic removal of undesirable clones.

Table 3.--Expected genetic gains for growth and form characteristics and wood specific gravity of Virginia and loblolly pines from selection in wild stands followed by roguing of the clonal seed orchards on the basis of progeny testing and clonal testing

	Expected gain from selection in natural forest stands				Expected gain from roguing on the basis of 4-year progeny tests				Expected gain from roguing on the basis of clonal tests				Unselected population mean	Total expected gain from two cycles of selection (percent)	
	i_1[1/]	h_1^2	σ_p	G_1	i_2[2/]	h_2^2	σ_f	G_2	i_3[2/]	h_3^2	σ_c	G_3	$\bar{X}$	(G_1+G_2)	(G_1+G_3)
LOBLOLLY PINE															
Height	2.66	0.01	6.12	1.9	0.80	0.15	0.726	2.0	0.80	0.08	3.74	3.5	8.73	3.9	5.4
					1.16	.15	.726	2.9	1.16	.08	3.74	8.0	8.73	4.8	9.9
M.A.H.G.	2.66	.07	0.31	2.6	.80	.15	.182	2.0	.80	.31	0.37	8.4	2.18	4.6	11.0
					1.16	.15	.182	2.9	1.16	.31	0.37	12.2	2.18	5.5	14.8
Straightness	2.66	.08	1.12	6.3	.80	.37	.276	4.3	.80	.25	1.26	13.3	3.78	10.6	19.6
					1.16	.37	.276	6.3	1.16	.25	1.26	19.3	3.78	12.6	25.6
Crown form	2.66	.02	1.03	1.6	.80	.23	.199	2.0	.80	.16	1.07	7.8	3.53	3.6	9.4
					1.16	.23	.199	3.0	1.16	.16	1.07	11.3	3.53	4.6	12.9
VIRGINIA PINE															
Height	2.66	0.04	5.24	8.1	0.80	0.33	0.426	3.3	0.80	0.12	2.30	6.5	6.85	11.4	14.6
					1.16	.33	.426	4.8	1.16	.12	2.30	9.4	6.85	12.9	17.5
Diameter	2.66	.01	1.14	2.4	.80	.15	.100	1.9	.80	.04	0.56	2.8	1.28	4.3	5.2
					1.16	.15	.100	2.7	1.16	.04	0.56	4.1	1.28	5.1	6.5
Straightness	2.66	.08	1.03	6.0	.80	.37	.224	3.6	.80	.06	1.09	2.9	3.66	9.6	8.9
					1.16	.37	.224	5.3	1.16	.06	1.09	4.1	3.66	11.3	10.1
Crown form	2.66	.04	1.02	2.6	.80	.43	.202	3.3	.80	.09	1.06	3.2	4.23	5.9	5.8
					1.16	.43	.202	4.8	1.16	.09	1.06	4.6	4.23	7.4	7.2
Wood specific gravity	2.66	.53	0.30	11.1	.80	.47	.015	3.0	.80	.25	0.30	3.1	.382	14.1	14.2
					1.16	.47	.015	4.3	1.16	.25	0.30	4.6	.382	15.4	15.6

Table 3 continued on next page

Table 3 (continued)

1/ i_1 = coefficient of selection intensity corresponding to a 1 percent intensity of selection in wild stands, i.e., $i_1 = 2.66$

2/ i_2 and i_3 = coefficients of selection intensity corresponding to the selection of 50 percent ($i_{(i)} = 0.80$) and 30 percent ($i_{(i)} = 1.16$) of the clones in the seed orchards.

h_1^2 = narrow-sense heritability estimated by regression of seedling progeny on parent trees,

h_2^2 = family mean heritability,

h_3^2 = narrow-sense heritability estimated by regression of seedling progeny on clonal parent,

σ_p = phenotypic variation of unselected natural loblolly pine population (Porterfield 1973) and phenotypic variation of 104 crop Virginia pine trees,

σ_c = phenotypic variation of clone means,

σ_f = phenotypic variation of half-sib family means,

G_1 percent = $(i_1 h_1^2 \sigma_p) \dfrac{100}{\bar{X}}$, G_2 percent = $2(i_2 h_2^2 \sigma_f) \dfrac{100}{\bar{X}}$, G_3 percent = $2(i_3 h_3^2 \sigma_c) \dfrac{100}{\bar{X}}$,

$\bar{X}$ = means of the 4-year-old commercial check seedlings included in the progeny tests,

M.A.H.G. = mean annual height growth.

maximum gain and reliability, only trees of the same age class and growing in similar environmental conditions should be selected. In addition, scions should be collected at the same position within the crown of each tree.

On a clonal basis, a seed orchard could be rogued 5 years after establishment depending on its growth rate and precocity of seed production. From that time on, the seeds produced would be improved by two cycles of selection. In addition, the gain resulting from roguing the orchard can be increased by initially using a larger number of clones and closer spacing of the ramets. At 20-foot spacing, using the same number of ramets per clone, 100 clones require less area than 50 clones with 30-foot spacing between ramets. The difficulty of progeny testing large numbers of clones limits the number of parent trees that can be initially included in the seed orchard; this problem can be overcome if clonal tests are used for initial roguing.

A breeding program using clonal testing could be begun as follows. First, select 100 phenotypically superior trees in wild forest stands at a maximum intensity of selection. Second, establish the 100 clones in the orchard. If the final spacing required for maximum seed production is 30 feet, the initial spacing should be 16 feet between the ramets. Third, after 5 years, if the growth is rapid and the fructification is early, rogue 50 percent of the clones on the basis of their vegetative performance. As shown in table 3, the expected gain is twice as high as from roguing 50 percent of the clones on the basis of 4-year-old progeny performance for height in loblolly and Virginia pines and for stem straightness and crown form in loblolly pine. After the orchard is in production, control pollinate the clones left to provide seedlings for advanced generation selection. A modified diallel type of mating design would provide reliable information about the mode of gene action and would produce the maximum number of unrelated families. On the basis of progeny performance, inferior clones that escaped the initial roguing could be liminated.

SUMMARY

An investigation of the inheritance of growth, form characteristics, and wood density of Virginia and loblolly pine was undertaken with the objective of determining the possibility of using vegetative clonal performance of parent trees selected from wild stands as a measure of their breeding value. Measurements were taken from three distinct but genetically related tree groups: parent trees, grafts of the parents, and control-pollinated progeny.

Analyses were made of total tree height, diameter, bole straightness, and crown form. Virginia pine wood density was also investigated.

Analyses of variance were performed on clones and seedling progenies, while regression and correlation analyses were used as measures of the degree of resemblance between related groups and to estimate heritabilities. Nested analyses of variance of clonal populations revealed highly significant genetic differences among clones for all characters. Variance component analyses done on progeny data indicated statistically significant differences in general combining ability. Narrow-sense heritability on an individual tree basis was estimated to be 0.30 to 0.05 for height, 0.07 for crown form and 0.09 to 0.13 for stem straightness of loblolly pine. Virginia pine narrow-sense heritabilities were as follows: height = 0.13, diameter = 0.06, straightness = 0.10, crown form = 0.20, and wood density = 0.38.

Narrow-sense heritabilities estimated by regression of seedling progeny on the mature parent trees were generally low and unreliable, reflecting the difficulty of predicting offspring juvenile performance on the basis of parental phenotypic measurement alone. Higher and more accurate estimates were obtained by regression of progeny on the clonal parent than by regression on the ortet. Heritabilities equal to 0.22, 0.12, 0.06, 0.08, and 0.25 were found for mean annual height growth, diameter, straightness, crown form, and specific gravity of Virginia pine.

Greater similarities between progeny and clonal parent than between progeny and mature parent tree make possible the use of clonal testing as a tool to increase and speed up genetic gains. Clonal testing of loblolly and Virginia pine is proposed as a supplement or substitute to progeny testing, especially for early roguing. A gain of 11 percent in mean annual height growth, 20 percent in straightness, and 9 percent in crown form are expected for loblolly pine following a selection intensity of 1 in 100 applied to wild forest stands plus roguing of 50 percent of the clones in a specially designed clonal test. Gains of 15 percent in height, 9 percent in straightness, 6 percent in crown form, and 14 percent in wood specific gravity are expected for Virginia pine after initial selection and roguing.

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PRESCRIPTION FOR THE AERIAL ENVIRONMENT OF A PLASTIC GREENHOUSE NURSERY

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ABSTRACT.-- Investigations into the aerial environment favoring rapid growth of tree seedlings in plastic greenhouses are described. Controllable factors studied were day and night temperatures, and high and low intensity extension of photoperiod; a confounding influence of carbon dioxide enrichment and high humidity was also examined. Experiments were designed within the limits of applicability of results to the greenhouse control system, and were made on three commercially important species: jack pine, black spruce, and white spruce. Recommendations are given for each species, and also a single prescription is given for greenhouses containing all three species. The merits of high and low intensity photoperiod supplements are discussed.

The idea of using controlled environments for rapid production of tree seedlings is not new, but only recently has the principle been applied to forest nurseries in Canada.

Development of controlled-environment nurseries in North America has been stimulated by a trend toward container-grown seedlings and increasing interest in mechanized production systems. Typically, controlled environment nurseries comprise plastic greenhouses with various systems of temperature and photoperiod control. Automatic watering is usually included and may incorporate a nutrient delivery system. More elaborate units include means for carbon dioxide enrichment of the atmosphere, humidity control, and high intensity light supplement. Forest tree seedling production is approaching the sophistication that has characterized commercial horticulture for many years.

Three important factors of environmental control systems are engineering feasibility, cost, and the plant's requirements. The first two are intimately related and readily assessed so usually dominate design of a unit. The plant's requirements, however, are often poorly understood. Despite several decades of research into tree growth, the nurseryman equipped with controlled

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environments does not have adequate information on the requirements of tree species, especially northern conifers.

This was the position of the Ontario Ministry of Natural Resources (OMNR) when they ventured into production of seedlings in controlled environments at Swastika, Ontario. Their objective was to produce two, and eventually three, batches of seedlings each year by extending the effective growing season and by accelerating growth during the first year. This paper is an account of a series of experiments that were conducted at the Canadian Forestry Service laboratories at Petawawa to prescribe the environments best suited to meet this objective.

The controlled environment facilities at the Swastika nursery consist of two plastic greenhouses (40 m long, 10 m wide, and 4 m high at center) fitted with raised platforms for pallets of containerized seedling trees. Main environmental control is for temperature, through heat exchangers in a plenum at the end of each greenhouse, and for photoperiod, through a series of overhead incandescent lamps providing night illumination of about 400 lux. Ventilators are used in hot weather. Atmospheric carbon dioxide can be increased by a propane burner, although the benefit is lost when ventilators are open. A central trough carries a motorized boom for spraying water and nutrient solutions. Each house holds about a million 5/8 inch tubelings.

The effects of day and night temperature, carbon dioxide enrichment, and photoperiod were tested on the three main species raised at Swastika--jack pine (*Pinus banksiana*), black spruce (*Picea mariana*), and white spruce (*Picea glauca*) to determine the optimum aerial environment for the species.

METHODS

As far as possible, materials and cultural methods used in the Swastika nursery were duplicated in the controlled environment experiments. Seed of the three species was sown in 5/8-inch plastic tubes. In the first three experiments a fine-screened 3- to-1 mixture of peat and vermiculite was used; in subsequent experiments tubes were filled with peat muck as used by the nursery. A nutrient solution (Ingestad 1967) was applied daily (except in Experiment 1, where solution was applied three times a week).

Unless stated otherwise, experiments were conducted in small growth cabinets with illumination of 22,000 lux provided throughout a 16 h photoperiod. The duration of each experiment was 8 to 12 weeks from sowing. Treatment effects were assessed from ovendry weight (95°C) and heights attained over this period.

Experiment 1--Effect of Daytime Temperature

After germination, about 100 tubelings of each of the 3 species were placed in each of 5 cabinets. Temperatures in the cabinets were 15, 20, 25, 30, and 35°C, respectively, during the day and 15°C at night. The range of temperatures tested was restricted to the practical limits of greenhouse operation. The tubelings and treatments were rotated weekly through the five cabinets to eliminate the cabinet effects as a source of experimental error.

Twelve weeks after sowing, 15 seedlings were taken from each species for individual analysis of roots and shoots and height measurements (table 1). For both spruce species a 25° day temperature yielded tallest and heaviest seedlings. Jack pine growth did not peak in a single temperature regime but remained high over a daytime range of 25 to 35°C. Evidently daytime temperature is less critical in jack pine than in spruces.

Experiment 2--Effect of Nightime Temperature

Experimental design was similar to Experiment 1. Four night temperatures were tested, 15, 20, 25, and 30°C with a daytime temperature of 30°C. Again, the test temperatures were based on practical limitations of greenhouse control at Swastika (table 2).

As in Experiment 1, temperature was most critical in spruce with both species achieving maximum height and weight with a night temperature of 20°C. Jack pine weight was unaffected by changes between 15 and 25°C, although height decreased slightly over this range.

The seedlings in Experiment 2 weighed approximately three times as much as the seedlings in Experiment 1. This is probably a result of differences in watering and feeding because the seedlings in Experiment 2 were given a daily top watering with nutrient solution that the Experiment 1 seedlings were not.

Experiment 3.--Effect of Carbon Dioxide Enrichment

Seedlings were raised as in Experiment 1 and subjected to either ambient or enriched CO_2 concentration. For enrichment CO_2 was bled into the growth cabinet from tanks of compressed gas and maintained at a concentration of between 1,010 and 1,150 ppm. The cabinet atmosphere was monitored continuously with an infra-red gas analyzer. Cabinets were maintained under a day/night regime of 30/15°C and 16 h photoperiod. The enriched cabinet was sealed to prevent excessive leakage of CO_2.

Results with jack pine in this experiment did not correspond to those obtained in previous work (table 3) (Yeatman 1970). Carbon dioxide enrichment apparently depressed shoot growth by about 11 percent although this was partly offset by a 40 percent increase in root growth. Root growth

Table 1.--Height and dry weight[1] of jack pine, white spruce, and black spruce grown for 12 weeks in day temperatures of 15 - 35°C and night temperatures of 15°C

Day temperature (C°)	Height	Dry weight Shoot	Root	Seedling
	cm [2]	g	g	g
JACK PINE				
15	7.2a	0.096a	0.038a	0.134a
20	10.0b	.172b	.059c	.231b
25	12.0c	.215xc	.053bc	.268bc
30	12.5cd	.219c	.045ab	.255bc
35	12.8d	.238c	.050bc	.288c
WHITE SPRUCE				
15	4.3a	0.030a	0.007ab	0.037a
20	4.6a	.051b	.008bc	.059b
25	5.6b	.068c	.010c	.078c
30	4.5a	.048b	.007ab	.055ab
35	4.2a	.034ab	.005a	.039a
BLACK SPRUCE				
15	4.6a	0.036a	0.010a	0.046a
20	5.8b	.071c	.015b	.086c
25	7.4d	.094d	.017c	.111d
30	6.4c	.079c	.013b	.092c
35	5.5b	.050b	.010a	.060b

[1] Mean of 15 seedlings

[2] Means followed by common letters are not significantly different at P = 0.05 by Duncan's Multiple Range Test.

Table 2.--Height and dry weight[1] of jack pine, white spruce, and black spruce grown for 12 weeks in day temperature of 30°C and night temperature 15 - 30°C

Night temperature (C°)	Height	Dry weight: Shoot	Dry weight: Root	Dry weight: Seedling
JACK PINE				
	[2] cm	g	g	g
15	18.1a	0.600a	0.096a	0.696a
20	17.8a	.579a	.108a	.687a
25	16.4b	.591a	.105a	.696a
30	14.2c	.482a	.094a	.576a
WHITE SPRUCE				
15	8.0b	0.197b	0.042a	0.239ab
20	10.5a	.264a	.042a	.306a
25	9.1b	.215ab	.030a	.245ab
30	8.1b	.196b	.036a	.232b
BLACK SPRUCE				
15	12.4a	0.247b	0.036b	0.283b
20	13.7a	.357a	.051a	.408a
25	13.5a	.296ab	.041ab	.337ab
30	12.4a	.258b	.039ab	.297b

[1] Mean of 15 seedlings.
[2] Means followed by common letters are not significantly different at P = 0.05 by Duncan's Multiple Range Test.

was also strongly stimulated in the spruces and significant increases in shoot growth occurred in these species.

Table 3.--Mean weight and height of 15 conifer seedlings grown for 12 weeks in ambient and enriched CO_2 concentrations (day/night temperature: 30/15°C)

CO_2	Shoot weight	Root weight	Height
JACK PINE			
	g	g	cm
Ambient	0.60	0.10	18.1
Enriched	.53	.14	16.4
WHITE SPRUCE			
Ambient	0.20	0.04	8.0
Enriched	.24	.06	7.4
BLACK SPRUCE			
Ambient	0.25	0.04	12.4
Enriched	.34	.07	12.7

The results with jack pine are believed to be the result of higher humidity in the sealed cabinet (rh = 80 to 85 percent in the CO_2-enriched cabinet compared to rh = 65 to 70 percent in the control cabinet). High humidity reduced evapotranspiration directly, both from the plants and from the soil surface. Seedlings were weighed every 2 or 3 days before watering; considerably less water was lost from seedlings in the enriched environment. Carbon dioxide enrichment induces stomatal closure which also reduces transpiration. The combined effect would be to promote water-logging in the soil and consequently to affect redox potential and nutrient exchange. Treatment seedlings of all three species were slightly chlorotic. Subsequent analysis revealed a total nitrogen content of between 11 and 33 mg/g in CO_2-enriched plants compared to 20 to 25 mg/g for controls.

The fact that better results with CO_2 enrichment were obtained with species of wetter habitats, and particularly with black spruce, supports the view that poor results with jack pine are more likely to be associated with soil moisture problems than with CO_2 enrichment itself.

A second experiment was conducted with jack pine in which drying loops were linked to atmospheres in the control and CO_2-enrichment cabinets. Jack pine will respond positively to CO_2 enrichment but humidity problems may arise (table 4). The need for more thorough experiments was obviated when OMNR nurserymen frequently found it necessary to augment the cooling system of greenhouses by ventilation which made enrichment impracticable.

Table 4.--Mean height and weight of 25 jack pine seedlings grown for 12 weeks in ambient and enriched CO_2 concentrations at different relative humidities (day/night temperatures: 30/15°C)

CO_2	r.h.[1]	Shoot weight	Root weight	Height
		g	g	cm
		[2]		
Ambient	low	0.48a	0.15a	19.2a
Ambient	high	.54ab	.18ab	21.3a
Enriched	low	.68b	.30c	20.9a
Enriched	high	.54ab	.23bc	18.4a

1 low = 65 to 70 percent r.h.; high = 80 to 85 percent r.h.
2 Means followed by common letters are not significantly different at p = 0.05 by Duncan's Multiple Range Test.

Experiment 4--Effect of Photoperiod

Extended photoperiods affect growth in a variety of ways depending on the physiological state of the plant and on the intensity of light provided. Low intensity (less than 1,000 lux) extension of photoperiod will usually prevent the onset of dormancy in young seedlings and appears to stimulate growth by effects on plant metabolism. At higher intensities (above 10,000 lux) both of these effects will be present, but in addition is stimulated by the significant increase in energy available for photosynthesis. Natural photoperiods can be supplemented by low intensity light at reasonable cost, but the cost of installing and operating entirely artificial high intensity lighting is usually prohibitive for production nurseries.

This investigation was conducted in two parts. First, as a demonstration, seedlings were grown in four high intensity photoperiods. The experiment was then repeated with low intensity extensions of a fixed high intensity photoperiod.

High intensity photoperiod

Thirty-six seedlings of each species were reared in tubes at day/night temperatures of 25/20°C in each of four growth cabinets. The cabinets provided illumination of 22,000 lux for 15, 18, 21, and 24 h photoperiods,

respectively, from a mixed source of fluorescent and incandescent lamps. As a precaution against unknown cabinet effects, the seedlings and treatments were rotated through the four cabinets at weekly intervals. The seedlings were harvested for growth measurement 8 weeks after sowing (table 5). All species grew faster under long photoperiods, with continuous light consistently yielding the heavier seedlings. Seedlings grown under continuous light were at least twice the weight of those grown under only 15 hours of light. The response of height growth was slight in all species. The shoot weight increase was principally in foliage.

Table 5.--Height and dry weight[1] of jack pine, white spruce, and black spruce seedlings grown for 8 weeks in photoperiods of 15, 18, 21, and 24 hours of high intensity light (day/night temperature: 25/20°C)

Photoperiod (h)	Height	Dry weight: Shoot	Dry weight: Root	Dry weight: Seedling
JACK PINE				
	cm	g	g	g
15	10.4a[2]	0.189a	0.062a	0.251a
18	10.8ab	.260b	.088b	.348b
21	11.4c	.331c	.127c	.458c
24	10.9b	.371d	.131c	.502d
WHITE SPRUCE				
15	4.8a	0.062a	0.011a	0.073a
18	5.0a	.080b	.015a	.095a
21	5.1a	.104c	.021ab	.125b
24	4.8a	.122d	.028b	.150c
BLACK SPRUCE				
15	6.5a	0.065a	0.014a	0.079a
18	6.7a	.090b	.021b	.111b
21	7.0a	.126c	.030c	.156c
24	6.7a	.145d	.033c	.178d

1 Mean of 36 seedlings

2 Means followed by common letters are not significantly different at p = 0.05 by Duncan's Multiple Range Test.

The cost of maintaining high intensity lighting is directly proportional to the duration of the photoperiod. But the response of seedling growth exceeds a simple linear relation: increasing photoperiod by 60 percent (from 15 to 24 hr) increased growth at least 100 percent. Thus in systems relying entirely on artificial lighting for high intensity illumination, long photoperiods are more efficient and more effective than short photoperiods.

Low intensity photoperiod

Eighteen seedlings per species were reared in each of four treatments for 10 weeks as for the high intensity experiment. Photoperiods were based on 14 h of high light intensity with 0, 2, 6, and 10 h of supplementary incandescent light of about 400 lux. The treatments and seedlings were rotated at weekly intervals (table 6).

Table 6.--Height and dry weight[1] of jack pine, white spruce, and black spruce seedlings grown for 10 weeks in photoperiods extended by low-intensity light (day/night temperature: 25°/20°C)

Photoperiod (h)	Height	Shoot	Root	Seedling
JACK PINE				
	cm	g	g	g
14 + 0	[2]12.3a	0.54a	0.20a	0.74a
14 + 2	13.1a	.43a	.19a	.62a
14 + 6	15.3b	.58a	.21a	.79a
14 + 10	15.1b	.57a	.19a	.76a
WHITE SPRUCE				
14 + 0	5.4a	0.063a	0.021a	0.084a
14 + 2	6.0ab	.075ab	.018a	.093a
14 + 6	6.0ab	.075ab	.018a	.093a
14 + 10	6.8b	.087b	.019a	.096a
BLACK SPRUCE				
14 + 0	8.3a	0.091a	0.018a	0.109a
14 + 2	8.1a	.098a	.021a	.119a
14 + 6	8.5a	.098a	.020a	.118a
14 + 10	8.2a	.105a	.018a	.123a

1 Mean of 18 seedlings.
2 Means associated by common letters are not significantly different at $p = 0.05$ by Duncan's Multiple Range Test.

Jack pine results were somewhat inconsistent, but there appeared to be some additional height growth under the long photoperiods. White spruce showed a steady, though moderate, increase in shoot weight and height growth while black spruce showed neither. In no species was root growth enhanced.

The additional growth of white spruce might justify photoperiod control. But results with other species do not support the use of low intensity photoperiod extension in the range tested. However, the base illumination of 14 h is comparable to photoperiods in mid-April and mid-August at the Swastika nursery. Attempts to rear seedlings earlier in the spring or later in summer would almost certainly require some low intensity extension of photoperiod to prevent early cessation of growth.

CONCLUSIONS AND RECOMMENDATIONS

The three northern conifers investigated--jack pine, black spruce, and white spruce--appeared to have similar requirements in the aerial environment. This simplifies the prescription for environmental control in nurseries rearing these species in plastic greenhouses.

The most suitable temperature for all three species is a 25°/20°C day/night regime. This is specific for spruces, yet lies within the broader range of 25-35°/15-25°C suitable for jack pine.

Photoperiodic effects can be divided into two broad categories, those related to development and those related to dry matter production. Even at low light intensities, photoperiod exercises great control over the development of a seedling. A short photoperiod will usually result in cessation of growth and the onset of dormancy; thus when natural day-lengths are critically short, photoperiods can be effectively and inexpensively extended through the use of low intensity incandescent lamps. But our results indicate that there is little gain in using very long photoperiods (more than 16 h) of low intensity supplements once the continuous growth of seedlings has been ensured.

The effectiveness of very long photoperiods would be different in systems employing high light intensity supplements. Additional light in the form of longer, high intensity photoperiods means more energy for photosynthesis and results in more and more dry matter growth; an increase in light of 60 percent (from 15 to 24 h) doubled dry matter growth in all three species in our experiment.

Daylength exceeds 14 hours between mid-April and mid-August at latitude 48°N and should not need supplementing. Photoperiod extensions earlier in spring and later in summer should maintain 14 hours of light. A preferable regime would be 16 hours of light, in view of the lesser vigour of greenhouse-grown seedlings.

The advantages of carbon dioxide enrichment depend largely on whether a greenhouse requires ventilation during hot weather. Concentrations up to 1,000 ppm or more are undoubtedly beneficial, especially when light intensities are high. But it is usually these conditions that call for ventilation to prevent excessively high temperatures. Carbon dioxide enrichment appears to be impracticable in summer in view of the limitations of cooling systems employed in many plastic greenhouses.

The prescription suggested for the aerial environment of a plastic greenhouse nursery is inexpensive to implement because both temperature and photoperiod optima are close to natural conditions. Implementation is simplified by the similar requirements of the three northern species, so that mixed or successive batches can be reared under the same conditions.

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MANAGEMENT OF TREE GROWTH AND RESEARCH PLANTATIONS

Donald A. Fraser[1]

ABSTRACT.--Reports vegetative growth and reproductive responses in white and black spruce resulting from: control of soil moisture by means of overhead sprinklers, photoperiod by means of incandescent lamps, and thermoperiod by means of heated plastic shelters. Increased lateral branch and diameter growth resulted in white spruce from irrigation(a). Continuous light (b), increased apical growth but no diameter. Raised temperature (c) forced early bud growth as well as early apical growth cessation. (b) plus (c) caused early bud growth and late apical growth cessation. (a) as well as (b) plus (c) resulted in early, more abundant male and female conelet production in white spruce. Root-pruning had an immediate, additional stimulatory effect, but subsequently reduced vigor had deletorious effects on conelet production. The responses in black spruce were similar. Photoperiod and gibberellic acid responses in growth chambers are briefly mentioned.

Understanding the basic ecology, physiology, and genetics of forest trees is essential for manipulating and interpreting the physical and biological factors of the environment. Moisture, nutrients, photoperiod, thermoperiod, and growth-influencing substances are physical factors that may be manipulated. Biological elements include the beneficial presence of nitrogen-fixing organisms in the soil, and the deleterious effect of insects and pathogens.

We conducted experiments to determine what effect these factors had on tree growth and on production of reproductive buds. The experimental work was conducted in special outdoor testing areas and in growth chambers. Although other species were also investigated, chief emphasis was on white (*Picea glauca* (Moench) Voss) and black spruce (*P. mariana* (Mill.) BSP.).

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FIELD EXPERIMENTS

Methods

In 1956 the Corry Lake Tree Physiology Area was established in Chalk River, Ontario, on a 3-acre site of loamy sand with adequate fertilization. It was designed for progressive plantings of white and black spruce and selected hardwood species for managing environmental factors. Special emphasis was placed on the following factors that might accelerate the production of flower primordia and consequent seed production in commercial plantations.

(1) Soil moisture was regulated with overhead irrigation sprinklers drawing untreated water from Corry Lake. During early stages of plantation establishment, white clover was sown around the young saplings to improve the soil and to limit competition from weeds present in the original field.

(2) Photoperiod was extended with incandescent lamps (Fraser 1966).

(3) Thermoperiod was altered with heated plastic enclosures that extended the frost-free period.

The control was the cleared 6-acre Loon Lake Physiology Area on a loam sand represented by moisture regimes from dry to wet (Fraser 1954). This control area was planted concurrently with the Corry Lake Physiology Area, so that growth under a natural environment could be compared with growth of trees treated to accelerate vegetative and reproductive growth.

Apical as well as diameter growth of leaders and lateral branches were measured periodically from March 21 to August 29, 1969 on 9-year-old white spruce. In addition, the development of reproductive buds was tallied annually for 9 years in four plantations of white spruce and one of black spruce, established in 1956 with 3-year-old seedlings of local provenances as follows:

1. White spruce under natural environment.

2. White spruce under natural light, but irrigated and fertilized.

3. White spruce under continuous light, irrigated, and fertilized.

4. Same as "3" but root-pruned twice in a circle 18 inches from the trunk to an 8-inch depth, when the saplings were 7 and 8 years old.

5. Black spruce under the same conditions as "3" and "4".

RESULTS AND CONCLUSIONS

Vegetative Growth Response

Soil Moisture--Apical and diameter growth of white spruce control trees were greatest on the dry site (fig. 1). However, greater lateral branch and diameter growth were found on the irrigated area where adequate moisture and nutrients were provided throughout the season. The influence of the natural range of moisture on radial growth of mature trees was reported earlier (Fraser 1956).

Photoperiod--Continuous light increased apical growth, yet more important was the longer period over which the apical extension took place, for this represented a longer time available for the formation of reproductive buds (fig. 1).

Thermoperiod--Raised temperatures altered the time of the period of apical growth, but did not affect diameter growth (fig. 1). When temperatures were raised in mid-April, when frost is still frequent under natural conditions, growth began in April rather than in late May. Therefore, temperature controls the time growth begins in the spring (Fraser 1972). However, growth also stopped earlier in the warmer environment.

The combination of continuous light and raised temperature caused apical growth to begin earlier and stop later (fig. 1). The first time the saplings were exposed to such an extended photoperiod a 30 percent increase in leader growth was obtained. This response gradually diminished when the extended photoperiod was continued over a period of years on the same saplings. Therefore, lengthened photoperiod will accelerate growth of nursery material but the next use should be when accelerated production of reproductive buds is desirable.

Reproductive Growth Response

The white spruce control trees developed reproductive buds when 13 years old: 8 percent male and 11 percent female buds which was less than one male and two females per plantation tree (fig. 2). A peak of 32 percent of the saplings produced male and 19 percent female buds with an average of 15 male and 9 female buds the next year. No reproductive buds were formed the following year.

When white spruce was grown under natural light, irrigated, and fertilized, reproductive buds were produced earlier and in larger quantities. Reproductive buds were first developed when these trees were 10 years old--5 percent of the trees produced male and 8 percent female buds both male and female buds averaged one per tree. When the saplings were 14 years old, 40 percent of the trees produced male and 33 percent female buds

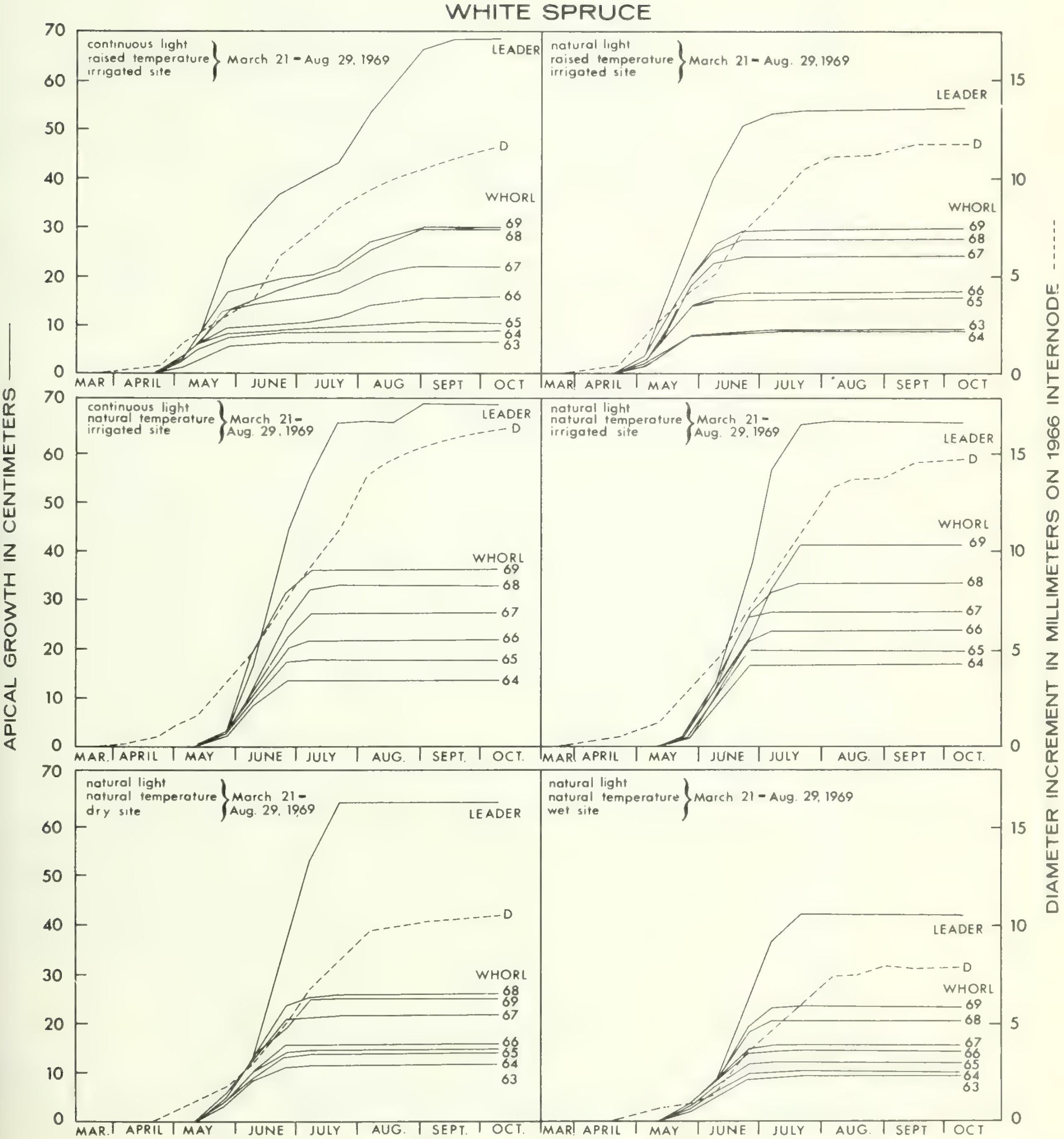


Figure 1.--Average leader (four trees per sample), lateral shoots (four branches per whorl), and diameter growth of 9-year-old white spruce grown under various combinations of photoperiod, thermoperiod, and soil moisture.

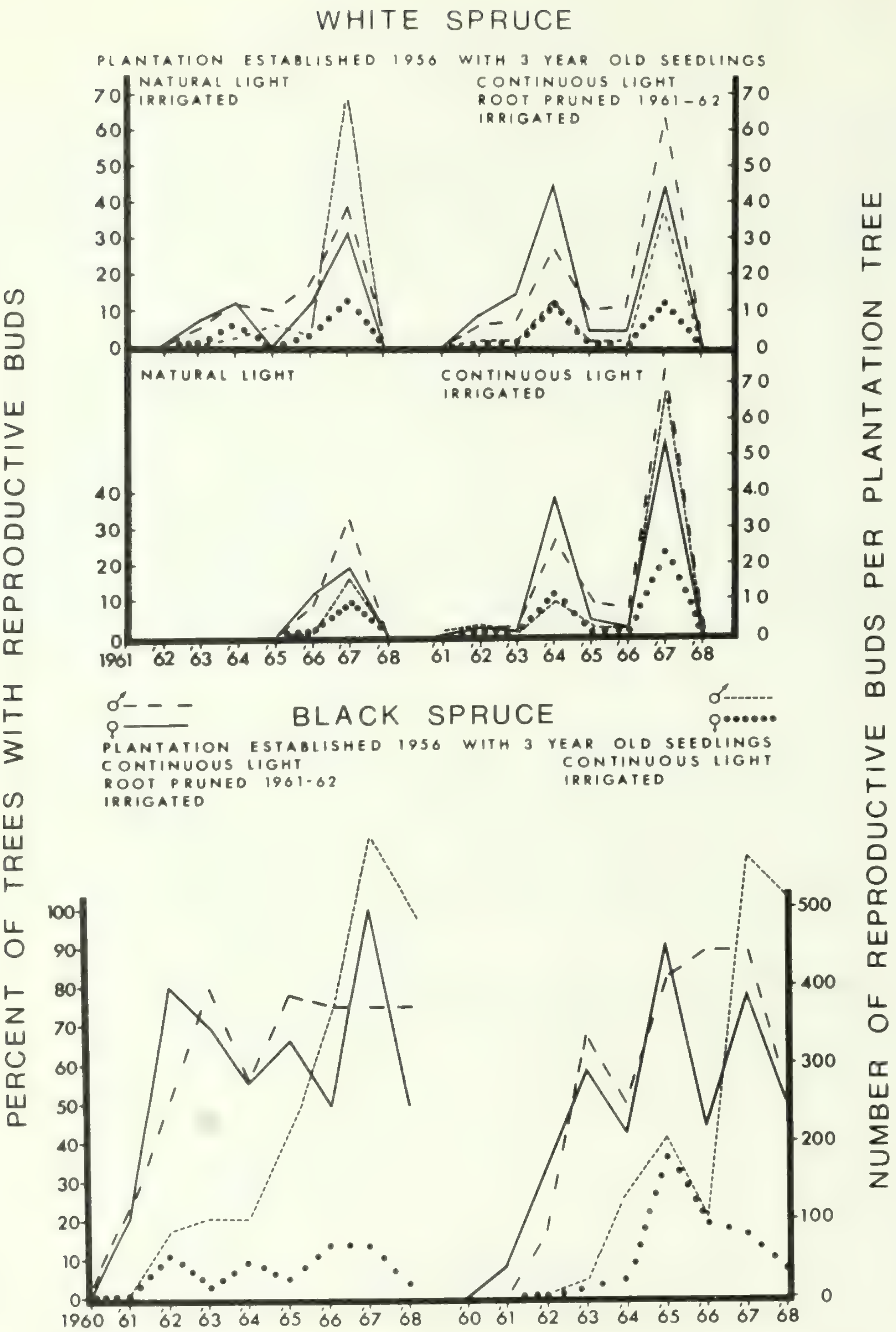


Figure 2.--White and black spruce trees with reproductive buds and reproductive buds per tree during the 1961-1968 period.

with an average of 70 male and 13 female buds per tree, compared with the 32 percent and 19 percent peak in the control trees.

White spruce saplings under continuous light in an irrigated and fertilized soil also produced reproductive buds earlier than those grown in a natural environment; 26 percent produced male and 40 percent female buds with an average of 10 male and 13 female buds per tree at an age of 11 years. In 1967 when all plantations had trees producing reproductive buds, this continuous light plantation had male buds on 74 percent of the trees and females on 53 percent with an average of 67 male and 23 female buds per tree.

Root-pruned trees produced reproductive buds more abundantly at a slightly earlier age--30 percent male and 45 percent female buds from an 11-year-old sapling, but 3 years later only 55 percent male and 45 percent female buds were produced compared with the 74 percent male and 53 percent female buds in the unpruned continuous light saplings.

Black spruce was also studied in the irrigated and fertilized Corry Lake Physiology Area plantation under continuous light in a preliminary experiment (fig. 2). Reproductive buds appeared when the saplings were 7 years old. Two years later, 80 percent of the root-pruned saplings were producing male buds under continuous light compared with 65 percent of the unpruned saplings; 100 percent of the root-pruned saplings produced female buds at an age of 14 years. Yet, this gave an average of only 50 female buds per tree, while the unpruned trees, although they were not developing uniformly, had a maximum of 200 female buds per tree 2 years earlier, when 90 percent of them produced female buds. Thus, root-pruned black spruce saplings produced more reproductive buds in the first year after root-pruning, but the number decreased later when the effect of reduced tree vigor due to root-pruning became evident.

It would appear that genetical response might be favored by the supply of nutrients alone, as attested in the white spruce by reproductive bud production at the earliest data. However, the two peaks in reproductive bud development indicate an overall effect of light, especially on the production of female buds. Both black and white spruce responded to root-pruning by immediate production of reproductive buds, but these trees did not remain as productive over several years as did the undisturbed trees. The method might, therefore, be suitable when only one year of high reproductive bud development is required.

GROWTH CHAMBER EXPERIMENTS

Borthwick et al. (1956) established that alternations of the light and dark period in combinations other than that of two uninterrupted periods within 24 hours will often stimulate additional growth. Thus, three different light-dark combinations were selected: (1) 12 hrs light and

Figure 3.--White spruce seedlings sprayed weekly with 100 ppm GA_3 and grown for 8 months under three different photoperiods as indicated under each seedling.

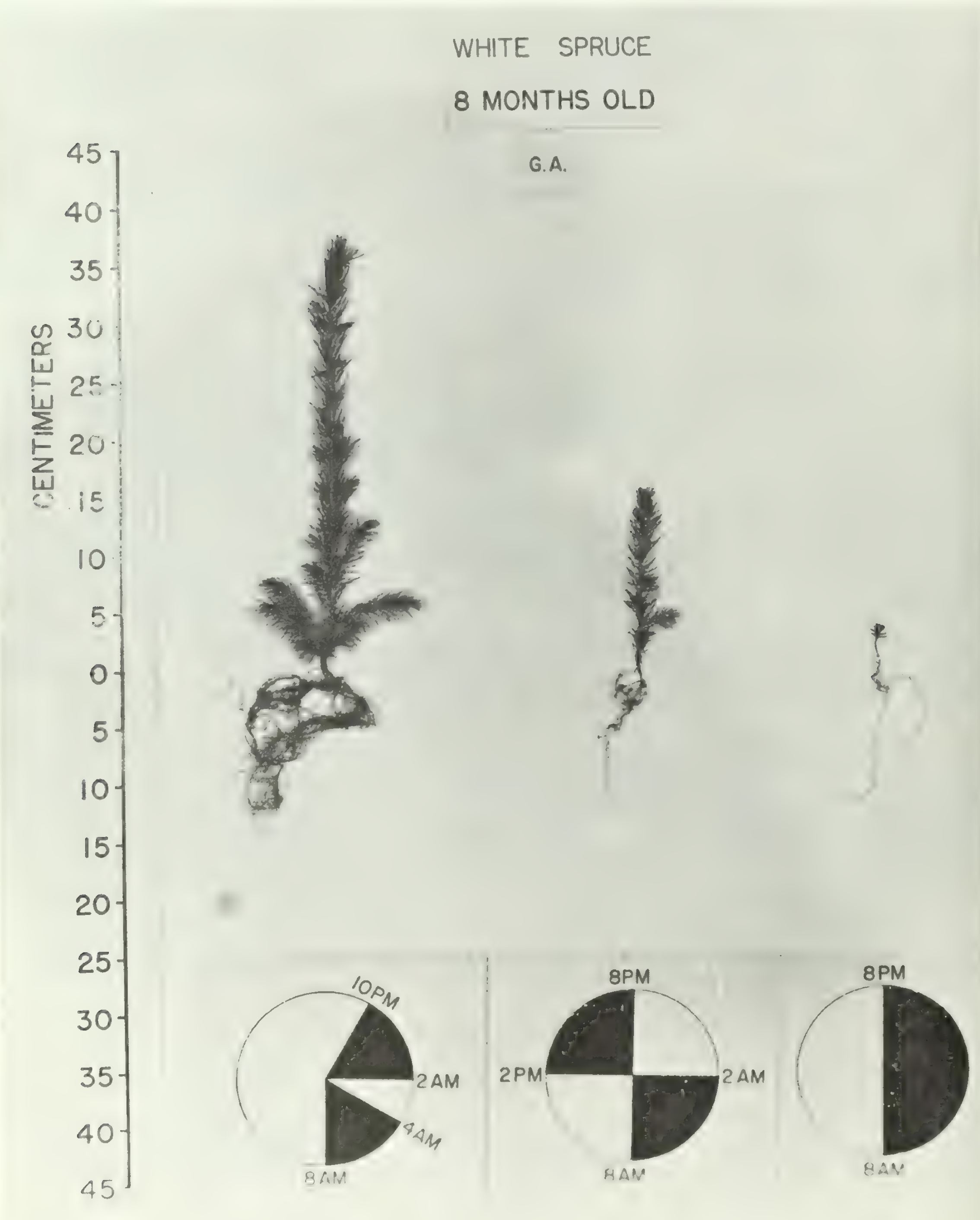
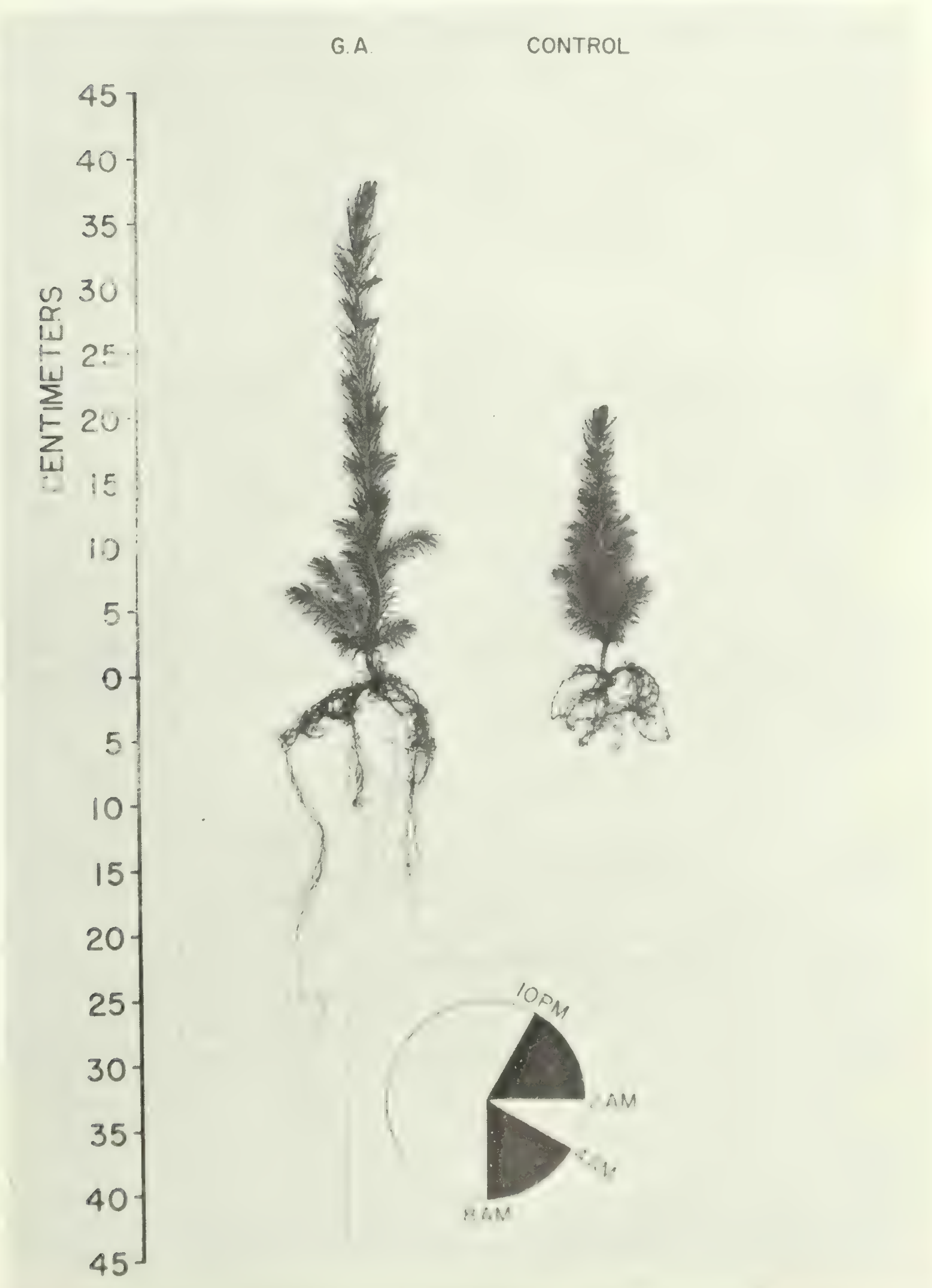


Figure 4.--White spruce seedlings sprayed weekly with 100 ppm GA_3 and grown for 8 months under the photoperiod as indicated below. Control seedling shown on the right grown under the same conditions but without gibberellic acid treatment.



12 hrs dark; (2) 6 hrs light and 6 hrs dark alternating; and (3) 14 hrs light, 4 hrs dark, 2 hrs light, and 4 hrs dark. The effect of the dark and light combinations on the growth of spruce seedlings follows that for herbaceous plants. The 6 hrs light and 6 hrs dark periods produced more growth than the 12 hrs light and 12 hrs dark periods. Greater growth was obtained with the 14 hr light period followed by 4 hrs dark, 2 hrs light, and 4 hrs dark (fig. 3).

Gibberellic acid (GA_3) was applied weekly as a foliar spray after germination at a concentration of 100 ppm. Its effect was additive to that of the lengthened photoperiod in that it accelerated leader growth (fig. 4). This response is opposite to that reported for white-cedar (*Thuja occidentalis* L.) where GA_3 application reduced apical growth and started flower primordia development within a few weeks of the first application (Fraser 1970).

SUMMARY

Management of tree growth in research plantations decreases the time required for seed production and hence assists in tree breeding experiments. Production of larger seedlings within a shorter time, if root systems are not reduced at the expense of shoot elongation, should provide material better suited for plant competition when out-planted.

ACKNOWLEDGMENTS

I wish to express my appreciation to members of the former Tree Physiology Section of the Petawawa Forest Experiment Station, Chalk River, Ontario, who assisted in the conduct of these experiments. Dr. E. E. Gaertner provided help both with the field work and in the compilation of results.

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BREEDING STRATEGY

M. A. K. Khalil 1/

ABSTRACT.--The development of breeding strategy is of paramount importance before breeding is begun in any given species. The purpose of improvement, degree and pattern of variation, and species biology are primary factors to be considered. The choice of the breeding method is another aspect to be taken into account, and selection, hybridization and mutation breeding are discussed here. Selection is well adapted to the characteristics of many species and is most commonly applied. The potential of hybridization has not been fully realized but must usually be combined with some form of selection. The use of special research environments, such as growth chambers, greenhouses and nurseries can give useful partial answers and direction to tree improvement in species where little basic information is available.

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ADAPTIVE VARIATION -- MANIFESTATIONS IN TREE SPECIES AND USES IN FOREST MANAGEMENT AND TREE IMPROVEMENT

Hans Nienstaedt 1/

ABSTRACT.--Adaptive variation and the genetic system that maintains adaptive fitness are described. It is emphasized that optimum fitness and genetic flexibility are opposing demands on the plant populations and have led to a compromise between fitness to existing environments and the capacity for further change. Using as examples phenological and edaphic adaptation, patterns of variation are discussed. Clinal variation is described and the importance of adequate sampling stressed in establishing discontinuous, ecotypic variation patterns. Variation patterns are character specific and may be highly complex depending on the pattern of the environmental variation -- clines within clines, clines within ecotypes and ecotypes within clines must exist within north temperate tree populations. The breeding systems and the factors determining the size of breeding groups are important aspects of the genetic system and must be considered in planning by foresters and tree breeders alike.

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PLUS TREE SELECTION IN BRITISH COLUMBIA

Gyula K. Kiss[1/]

ABSTRACT.--Two plus tree selection programs developed by the Research Division of the British Columbia Forest Service are discussed. The first of the programs developed for coastal Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) is a strict phenotypic selection program. Untested ramets of plus trees thus selected are established in seed orchards for seed production. The second program developed for interior spruces (white spruce, *Picea glauca* (Moench) Voss and Engelmann spruce, *P. engelmannii* Parry) employs a much more relaxed selected standard followed by open pollinated progeny trials. Advantages and disadvantages of both programs are discussed. Evaluation and recommendations are given based on experience gained during execution of the program.

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PROGENY TESTING IN PRACTICAL TREE IMPROVEMENT

J. W. Wright[1/]

ABSTRACT.--Good quality planting stock and good plantation care during the early years are very important. A well executed progeny test of moderately good design usually gives much more information than a poorly executed experiment of the most refined design. Half-sib progeny tests are less expensive, and give less gain and information than full-sib progeny tests. The cost, gain and information ratios between the two types vary considerably, depending on several factors. Often, with northern conifers, half-sib tests are preferable for first-generation work and full-sib tests in more advanced breeding programs. Progeny tests often need to contain a few hundred families. With tests that large it is desirable to compute optimum family size (often smaller than has been used in the past) and to consider carefully the effects of plot size and number of replications on efficiency; otherwise the tests may become unmanageable. A variation of the randomized complete block design is often regarded as the most practicable for large tests. A few hints are included as to desirable measurement and analysis procedures.

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THE ECONOMICS OF TREE IMPROVEMENT

A. Carlisle and A. H. Teich[1/]

ABSTRACT.--The report discussed the sources of costs and benefits of tree improvement in the context of plantation economics, and considers the ways a forester can control the profitability of establishing and managing forests. The response of Canadian tree species to selection and breeding, the ways tree improvement can help the forester, the costs and benefits of different tree improvement strategies, and quantification of costs and benefits are described. The sources of cost in tree improvement research, development and the plantation operation are compared. Future research needs are suggested.

1/ Canadian Forestry Service, Petawawa Forest Experiment Station, Chalk River, Ontario.

TREE SEED PROGRAM IN ONTARIO

C. H. Lane[1/]

ABSTRACT.--The regeneration program in the province of Ontario requires large quantities of tree seed annually. It is estimated that 1 billion viable seeds will be required to meet the 1975 needs of the program. Forest tree improvement has been developed to effectively improve the availability of tree seed and to improve seed quality on a scale sufficiently massive to meet the requirements of the reforestation program.

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SEED ORCHARDS

J. P. van Buijtenen and E. M. Long[1/]

ABSTRACT.--The objective of a seed orchard is to mass produce improved seed of the desired quality as economically as possible, and usually also as quickly as possible. The major steps involved are: (1) mass selection of desirable trees; (2) establishing the seed orchard; (3) progeny testing the seed orchards, and (4) roguing the seed orchards on the basis of results of the progeny tests. Seed orchard establishment includes the following major steps: site selection, site preparation, seed orchard design and graft establishment. Site fertility, drainage and location are all important considerations. Site preparation should be done thoroughly but usually presents no serious problems. Spacing should be such that the orchard will not require roguing before information from progeny tests is available, but close enough to give reasonable cone production at an early age. The design should consider such factors as providing a sufficient number of clones to form an adequate genetic base, optimizing cross pollination among clones, providing an adequate supply of improved pollen for the orchard, minimizing the proportion of contaminating pollen, and limiting the amount of inbreeding in the orchard. Three systems of handling grafts are in common use: pot grafting, bed grafting, and field grafting. Each of them is an acceptable method but has its own advantage and disadvantages. Seed orchard management practices are designed directly or indirectly to keep seed orchard trees healthy and to produce the maximum amount of seed. Increased flower production is secured by a combination of subsoiling, irrigation and fertilization. The seed orchard is protected and kept in a healthy condition by mulching, fire protection, protection from diseases and insects, and proper care of the orchard during harvesting.

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FOREST TREE SEED QUALITY

B. S. P. Wang[1]

ABSTRACT.--With the increase in reforestation in Canada, seed is becoming a valuable commodity because of increasing demand. Seed production is governed by many factors, but this paper only discusses seed quality as affected by the post-harvest handling of cones and processing, testing, storing and shipping of seeds. To improve seed quality and the economic use of collected seeds, a close control is required from time of cone collection through cone handling, and processing, testing and storage to shipping of the seeds for field sowing. Until all these factors are adequately controlled, the success of reforestation programs is unpredictable.

1/ Canadian Forestry Service, Petawawa Forest Experiment Station, Chalk River, Ontario.

☆ U.S. Government Printing Office: 1976—670-065/6 Region No 6

USDA Forest Service.
1976. Proceedings of the Twelfth Lake States Forest Tree Improvement Conference, August 1975. USDA For. Serv. Gen. Tech. Rep. NC-26, 206 p., illus. North Cent. For. Exp. Stn., St. Paul, Minn.

Presents 20 papers concerning recent research in forest genetics, physiology, and allied fields. Species discussed include cottonwood, white spruce, jack pine, white pine, aspen, and others. Emphasizes the role of tree improvement in increasing wood-fiber production. Includes abstracts from papers presented at the Fifteenth Canadian Tree Improvement Association Meeting.

OXFORD: (77): 165.3--01:946.2. KEY WORDS: tree breeding, fiber production, forest genetics, seed orchards.

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AMERICAN REVOLUTION BICENTENNIAL 1776-1976

USDA FOREST SERVICE
GENERAL TECHNICAL REPORT NC- 2 7

WHERE TO FIND WEATHER AND CLIMATIC DATA FOR FOREST RESEARCH STUDIES AND MANAGEMENT PLANNING

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CONTENTS

Surface Weather Observations 1
- Climatological Data 1
- National Fire-Weather Data 1
- Barmometer Watersheds 1
- Local Climatological Data 2
- NOAA Form FM-1 2
- Climatological Data, National Summary 3
- Hourly Precipitation Data 3
- Storage-gage precipitation data for Western United States 5
- Snow Cover Survey 5
- Westside Mountain Weather and Avalanche Network 5
- Water Supply Outlook 6
- Weekly Weather & Crop Report 6
- Storm Data 7
- Daily Weather Maps (Weekly Series) 7
- Synoptic series, daily weather maps, Northern Hemisphere sea level & 500-millibar maps & data tabulations 7
- Atmospheric Turbidity and Precipitation Chemistry Data 8

Climatic Summaries 8
- Climate and Man 9
- Climatic Atlas of the United States 9
- Climatological Substation Summaries (Plus Other Local Summaries) 9
- World Wide Airfield Climatic Data 9
- Weather Bureau Technical Papers 11
- Summary of Hourly Observations 12
- Heating Degree Day Normals, Monthly Normals of Temperature, Precipitation, and Heating Degree Days (Also Daily) 12

Historic Data 12

For More Information 13

Selected References 13

Appendix.--Status of the Climatological Program in Each State (1976) 13

North Central Forest Experiment Station
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1977

WHERE TO FIND WEATHER AND CLIMATIC DATA FOR FOREST RESEARCH STUDIES AND MANAGEMENT PLANNING

Donald A. Haines

Weather and climatic[1] data are needed r a variety of forest research studies d management planning. Much of the in- rmation required is routinely recorded d published. This paper lists these urces and tells where and how to find em.

SURFACE WEATHER OBSERVATIONS

Many management systems or research udies that require meteorological data ed only a daily reading of weather in- ruments. Others require the investigator t establish a weather station or network o stations and take observations. But a k owledgeable investigator may be able to u existing resources and save time and ney. Consequently, one of the first steps i study design is to decide upon meteor- o gical data needs and then determine w ch weather-observing networks already i operation may fill the need. In many S tes the local Climatological Office is a ood place to find this information (pendix).

Climatological Data

The National Oceanic and Atmospheric A inistration's (NOAA) monthly publication, *C matological Data*[2], is the best known and most widely used source containing weather information. It is issued for each State or combination of States. Individual issues may list over 200 observing stations with an identifying map and an index describing each site. Data include a daily precipitation table (fig. 1), a daily maximum and minimum temperature table (fig. 2), a general data table, and a daily snowfall and snow-on-the-ground table (in season). The issue may also include daily information on evaporation, wind, and soil temperature for a small number of locations.

National Fire-Weather Data

National Fire-Weather Data is a collection of computerized historic weather observations from more than 800 stations monitoring weather once daily, during early afternoon. The 1-1/2 million records in the archives extend back to 1955. Information includes state-of-weather, maximum and minimum temperature and relative humidity, dry and wet bulb temperature, fuel moisture timelag computations, vegetation condition, wind, precipitation amount and duration, lightning activity, risk factors, and fuel models (since 1974). Details on data acquisition may be obtained from the USDA Forest Service, Mountain Meteorology Project, Rocky Mountain Forest Experiment Station, 240 W. Prospect St., Fort Collins, Colorado 80521.

Barometer Watersheds

A network of stations was established by the USDA Forest Service in 1963-1964 under the title of *Barometer Watersheds*. Each watershed area (originally 21 but now 15) has at least one major weather station and almost all record solar radiation, air temperature and relative humidity at two levels, wind velocity, precipitation amount,

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[1] *As distinguished from climate, weather c sists of the short-term variations of the at osphere. Weather is the product of the i eraction of numerous natural elements; t long-term statistical computations of t se various elements collectively define t climate.*

[2] *All NOAA meteorological publications m be ordered from: the National Climatic C ter, Federal Building, Asheville, North C olina 28801.*

DAILY PRECIPITATION

MISSOURI
NOVEMBER 1976

STATION	TOTAL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
NEVADA SEWAGE PLANT	07															T											.07					
OSCEOLA	.28																										.28					
POMME DE TERRE DAM	.63																										.50	.13				
SEDALIA WATER PLANT	58																								.04		.17	.37				
STOVER	1.43																								T		1.18	.24				
VERSAILLES	1.88																										1.88					
WARRENSBURG 2 SSE	D .61																						T		D .05			.53	.03			
WARSAW 1	.85																										.42	.43				
WINDSOR	.52																											.52				
x x x																																
WEST OZARKS 04																																
ANDERSON	.28												.20			.08											T					
BILLINGS 1 N	.31											T	.08														.23	T				
BOLIVAR 1 NE	.78	T										T														.05	.74	T				
BUFFALO 3 S	1.66											.11	T														1.55					
CARTHAGE	.53																										.53					

Figure 1.--*Sample daily precipitation table from* Climatological Data.

DAILY TEMPERATURES

MISSOURI
NOVEMBER

STATION		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	AVERAGE
OSCEOLA	MAX	65	65	55	42	50	68	55	60	69	57	43	36	37	42	47	55	56	73	62	60	47	41	40	63	65	55	30	20	27	38		
	MIN	27	38	29	27	14	33	26	15	39	25	30	13	14	19	17	20	32	40	35	29	30	21	28	18	37	30	15	5	[illegible]	[illegible]		
POMME DE TERRE DAM	MAX	57	63	64	57	38	49	65	51	58	68	53	37	36	38	42	48	41	56	74	61	60	45	39	44	62	65	58	26	21	28		
	MIN	32	35	36	37	17	25	31	18	24	29	33	14	13	15	26	22	26	33	35	31	30	20	20	22	31	49	21	11	6	[illegible]		
SEDALIA WATER PLANT	MAX	56	63	64	51	36	48	60	46	56	66	45	34	33	36	43	45	44	55	72	59	55	43	37	34	52	65	42	22	20	23		
	MIN	30	34	30	28	18	19	30	17	18	29	28	17	14	16	22	22	24	34	31	25	25	21	21	23	26	42	21	11	5	6		
VERSAILLES	MAX	62	65	58	46	47	64	57	55	67	60	43	35	34	43	48	40	57	73	65	59	47	41	35	59	65	63	38	28	25	33		
	MIN	32	43	35	25	17	36	22	16	30	28	29	17	13	18	20	22	25	36	33	27	21	19	22	21	41	37	16	10	5	8		
WARRENSBURG 2 SSE	MAX	58	62	66	56	37	48	65	49	51	69	46	36	34	36	42	43	39	52	73	54	57	45	39	35	59	63	38	20	22	25		
	MIN	37	38	35	26	20	25	24	22	21	28	20	13	12	16	22	24	25	30	35	29	29	17	18	21	28	35	18	7	5	5		
WARSAW 1	MAX	65	65	62	52	50	68	58	59	69	63	47	35	36	44	48	44	58	75	67	61	51	42	42	61	66	64	38	23	25	35		
	MIN	27	38	27	27	14	29	25	14	37	24	30	12	11	18	24	18	32	36	31	25	29	20	27	20	31	38	18	10	[illegible]	4		
WINDSOR	MAX	55	63	65	55	37	49	63	49	56	68	49	35	34	37	43	44	38	55	72	59	58	45	40	36	57	64	46	22	22	25		
	MIN	33	34	35	26	17	18	30	20	20	31	29	16	16	16	25	21	22	32	39	30	29	19	20	22	23	43	20	9	5	7		

Figure 2.--*Sample daily maximum and minimum temperature table from* Climatological Data.

snow depth, water quality, and streamflow. Many stations also include soil temperature, soil moisture, and sedimentation rates; few take stream channel measurements. At most stations information is read hourly. Data are usually archived with the Specialist for Hydrology at Forest Service Regional Offices, however, archiving methods vary from Region to Region.

Local Climatological Data

If an expanded network of more detailed weather records is required, the information may be obtained from another NOAA issue, *Local Climatological Data*. This single-sheet monthly publication summarizes a wide variety of observations taken hourly at the more than 300 first-order stations of the NOAA National Weather Service. It includes temperatures for each day, dew points, degree days, weather types, pressure, wind, sunshine, sky cover, and precipitation amounts for each hour of the month (fig. 3). If the particular station operates round-the-clock, the reverse side of the publication includes observations taken at 3-hour intervals (fig. 4).

NOAA Form FM-1

If *Local Climatological Data* does not give sufficient detail, hourly observations can be obtained for first-order stations by requesting copies of Form FM-1 10A & B from the National Climatic Center. These are the original observer entries and often have a variety of information not shown in the published format.

LOCAL CLIMATOLOGICAL DATA

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
ENVIRONMENTAL DATA SERVICE

LANSING, MICHIGAN
NATIONAL WEATHER SERVICE OFC
CAPITAL CITY AIRPORT
DECEMBER 1975

LATITUDE 42° 47′ N LONGITUDE 84° 36′ W ELEVATION (GROUND) 841 FT. STANDARD TIME USED: EASTERN WBAN #14836

DATE	TEMPERATURE °F MAXIMUM	MINIMUM	AVERAGE	DEPARTURE FROM NORMAL	AVERAGE DEW POINT	DEGREE DAYS BASE 65° HEATING	COOLING	WEATHER TYPES ON DATES OF OCCURRENCE 1 FOG 2 HEAVY FOG X 3 THUNDERSTORM 4 ICE PELLETS 5 HAIL 6 GLAZE 7 DUSTSTORM 8 SMOKE, HAZE 9 BLOWING SNOW	SNOW, ICE PELLETS OR ICE ON GROUND AT 07AM IN.	PRECIPITATION WATER EQUIVALENT IN	SNOW, ICE PELLETS IN.	AVG STATION PRESSURE IN. ELEV. 874 FEET M.S.L.	WIND RESULTANT DIRECTION	RESULTANT SPEED M.P.H.	AVERAGE SPEED M.P.H.	FASTEST MILE SPEED M.P.H.	DIRECTION	SUNSHINE MINUTES	PERCENT OF POSSIBLE	SKY COVER TENTHS SUNRISE TO SUNSET	MIDNIGHT TO MIDNIGHT	DATE
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	26	20	23	-9	14	42	0	9	T	.07	1.8	29.15	23	16.9	17.7	28	SW	3	1	10	10	1
2	33	22	28	-3	18	37	0		2	.05	1.1	29.04	23	7.3	12.9	23	W	26	5	10	9	2
3	30	16	23	-8	13	42	0		T	.02	.6	29.30	28	4.9	6.5	14	NW	405	73	3	5	3
4	40	25	33	2	22	32	0		1	0	[illegible]	29.17	13	10.3	10.5	15	SE	482	87	2	4	4
5	60	35	48	18	40	17	0	1 8	0	.13	[illegible]	29.04	19	14.0	14.2	21	SW	173	31	6	5	5
6	57	22	40	10	24	25	0	1	0	.67	T	29.36	34	9.1	13.5	22	N	313	57	5	5	6
7	33	18	26	-3	17	39	0		0	[illegible]	0	29.46	07	4.0	5.6	11	SE	212	39	[illegible]	6	7
8	34	22	28	-1	22	37	0	1 8	0	.07	.7	29.19	06	4.8	4.9	13	E	48	9	10	9	8
9	31	28	30	1	23	35	0	1 8	1	.04	.7	28.94	34	5.4	7.8	13	NW	2	0	10	10	9
0	34	19	27	-1	22	38	0	6 8	1	.02	.5	28.93	22	10.3	11.4	20	SW	98	18	9	8	10

Figure 3.--*Sample of front side of* Local Climatological Data.

OBSERVATIONS AT 3-HOUR INTERVALS

SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	16THS MILE	WEATHER	TEMPERATURE AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	SPEED KNOTS
DAY 01										
8	80	15			12	11	05	73	20	7
10	25	4		SW	16	15	12	84	18	9
10	60	7		SW	18	17	14	84	18	4
10	15	1		S	20	20	19	96	18	7
10	12	5		SF	24	23	21	88	28	11
8	200	7			24	23	18	78	26	15
10	200	9			20	19	15	81	25	11
10	70	11			21	19	14	74	23	10
DAY 04										
10	7	3		F	17	17	16	96	00	0
10	7	3		SF	16	16	16	100	25	4
10	7	2	8	SF	18	18	18	100	28	5
10	5	1		SF	19	19	18	96	28	11
4	UNL	13			22	21	17	81	26	15
10	17	9			22	21	17	81	26	12
10	12	9			21	21	19	92	27	13
10	11	9			21	21	19	92	27	8

SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	16THS MILE	WEATHER	TEMPERATURE AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	SPEED KNOTS
DAY 02										
10	16	2		SW	18	18	16	92	25	11
10	12	0	12	SW	15	15	13	92	35	7
7	23	6		SW	10	10	07	88	36	8
0	UNL	15			04	03	-06	63	01	10
0	UNL	15			04	02	-13	44	02	13
0	UNL	15			03	01	-23	28	27	5
0	UNL	15			-01	-02	-20	39	24	7
0	UNL	15			05	05	-22	43	24	4
DAY 05										
10	15	7			21	20	18	88	20	8
10	17	5		GF	18	18	16	92	21	10
10	11	5		GF	20	20	19	96	23	9
10	13	5		F	23	23	21	92	29	10
10	16	7			26	25	21	81	29	5
10	19	7			27	25	21	78	[illegible]	[illegible]
10	17	7			23	22	20	88	12	6
10	80	7			22	22	20	92	12	9

SKY COVER TENTHS	CEILING HNDS. OF FT.	VISIBILITY WHOLE MILES	16THS MILE	WEATHER	TEMPERATURE AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	SPEED KNOTS
DAY 03										
7	UNL	15			-01	-02	19	41	24	7
9	80	15			01	00	-16	44	22	3
8	80	15			06	04	07	55	18	8
10	70	15			09	06	08	45	17	13
10	20	2		S	12	10	01	56	16	10
10	15	1	8	S	11	10	06	80	12	11
10	17	1	8	S	12	12	10	92	12	8
10	17	3		S	15	15	13	92	12	8
DAY 06										
10	8	5		F	22	22	21	96	15	13
10	8	3		F	23	23	22	96	14	10
7	70	5		F	25	25	24	96	14	11
10	200	5		H	27	26	23	85	18	11
10	50	7			32	30	25	75	22	6
10	10	1		SF	31	30	28	89	20	5
10	8	0	12	SF	30	30	30	100	24	4
10	5	0	12	SF	29	29	28	96	31	8

NOTES

CEILING
UNL INDICATES UNLIMITED

WEATHER

- * TORNADO
- T THUNDERSTORM
- Q SQUALL
- R RAIN
- RW RAIN SHOWERS

Figure 4.--*Sample of back side of* Local Climatological Data.

Climatological Data, National Summary

Generalized data are published monthly inthe NOAA *Climatological Data, National Sumary*. It summarizes general weather and rier and flood conditions (figs. 5 and 6). Itincludes base weather data for many sttions, summary tables of temperature an precipitation extremes for each State, a torm summary (fig. 7), cooling and heatin degree days (fig. 8), and solar radiatin intensities at selected stations. It alo contains types of data not usually of cocern to forest-range operations such as toal daily amounts of ozone in the atmosphre, average height, temperature, and reultant winds at selected pressure surfaes, and tracks of the centers of cyclnes and anticyclones.

In addition, the three aforementioned NOAA publications include annual supplements that summarize much of the daily data. Usually a table of normals, means, and extremes based on long periods of record are compiled for the weather elements.

Hourly Precipitation Data

A number of more specialized publications concentrate on a single weather element. One of the better known is NOAA's *Hourly Precipitation Data*. This monthly issue presents daily and hourly precipitation data from stations equipped with automatic recording gages. The first section of each issue gives tables similar to those in figure 1. The second section gives hourly precipitation (fig. 9).

FLOOD STAGE DATA

(All dates in June unless otherwise specified)

JUNE 1974

River and station	Flood stage	Above flood stages -dates[2] From–	Above flood stages -dates[2] To–	Crest[1] Stage	Crest[1] Date[2]
	Ft			Ft	
HUDSON BAY DRAINAGE					
Souris River					
Bantry 8 E, N. Dak	11	Apr 11	14	13.13	May 22
Westhope 7 NE, N. Dak	10	Apr 15	1/	16.62	Apr 26
Pembina River					
Neche, N. Dak	18	May 21	2	21.96	May 22
ATLANTIC SLOPE DRAINAGE					
Lumber					
Lumberton, N. C	9	2	5	9.5	3
Saluda					
Upper Mississippi Basin-Cont'd					
West Fork Cedar River					
Finchford, Iowa	12	7 9	7 13	12.07 14.00	7 11
Shell Rock River					
Shell Rock, Iowa	12	9	11	#12.89	10
Beaver Creek:					
New Hartford, Iowa	8	L	L	#12.37	[illegible]
Blackhawk Creek.					
Hudson, Iowa	12	9 22	11 24	#15.43 #15.99	10 23

Figure 5.--*Sample of* **Climatological Data, National Summary** *sheet for flood stage data.*

GENERAL SUMMARY OF NATIONAL FLOOD EVENTS

MARCH 1975

Basins and Streams	FLOOD EVENT	Lives Lost	Preliminary Estimate of Property Damage (thousands of dollars)
	LOWER MISSISSIPPI BASIN		
Mississippi tributaries in Tennessee	Major flooding struck western Tennessee as a result of the heavy rains of the 13th-14th with amounts of up to at least 8 inches reported for the storm. Flooding is rather rare in this area. The reporting network is not well developed and much flood data is not available. On many smaller streams flood stages have not yet been defined. However, it appears that flooding occurred on nearly all streams in the area. Crests more than 10 feet over flood stage occurred on the Obion River and the North and South Forks of the Forked Deer River. Damage in Union City in the Obion River Basin was estimated at $500,000 with 15 homes evacuated. In the Forked Deer River Basin 5 families were evacuated at Dyersburg with $50,000 damage. At South Fulton in the Hatchie River Basin 1,000 people were evacuated with losses of $2 million. Flooding was also reported on the Loosahatchie, and Wolf Rivers and on Nonconnah Creek. The storm of the 27th-29th also caused flooding on most of these streams of somewhat lesser magnitude.	0	3,000

Figure 6.--*Sample of* **Climatological Data, National Summary** *sheet for flood events.*

STORM SUMMARY

JUNE 197

STATE	TORNADOES Number	TORNADOES Days	TORNADOES Deaths	TORNADOES Injuries	TORNADOES †Damage	HAILSTORMS Deaths	HAILSTORMS Injuries	HAILSTORMS †Damage Property	HAILSTORMS †Damage Crops	WINDSTORMS Deaths	WINDSTORMS Injuries	WINDSTORMS *Damage Property	WINDSTORMS *Damage Crops	LIGHTNING Deaths	LIGHTNING Injuries	LIGHTNING †Damage Property	LIGHTNING †Damage Crops	@ HEAVY SNOWSTORMS AND BLIZZARDS Deaths	@ HEAVY SNOWSTORMS AND BLIZZARDS Injuries	@ HEAVY SNOWSTORMS AND BLIZZARDS *Damage Property	@ HEAVY SNOWSTORMS AND BLIZZARDS *Damage Crops	# ICE STORMS Deaths	# ICE STORMS Injuries	# ICE STORMS *Damage Property	# ICE STORMS *Damage Crops	∅ ALL OTHER Deaths	∅ ALL OTHER Injuries	∅ ALL OTHER †Damage Property	∅ ALL OTHER †Damage Crops
Alabama									5			5		1	1														
Alaska												4																	
Arizona	4	3	1	40	5							5																	
Arkansas	3	1	4	112	7			3	C		8	5		3	1	4	C									2	1	[illegible]	C
California																													
Colorado								3	5		3	4	4		3					4								3	
[illegible]	1	1			3																								
Delaware																													
Florida	4	4							3			5	4	8	6	4										3		7	4
Georgia	3	2			1			4	6		2	5	5			3	4											4	4

Figure 7.--*Sample of* **Climatological Data, National Summary** *sheet for storms.*

HEATING DEGREE DAYS

(Base 65°F.)

APRIL 1976

State and station	Current season: This month	Current season: Period July through this month	Normals: July through this month	State and station	Current season: This month	Current season: Period July through this month	Normals: July through this month	State and station	Current season: This month	Current season: Period July through this month	Normals: July through this month	State and station	Current season: This month	Current season: Period July through this month	Normals: July through this month
ALABAMA				IDAHO				NEBRASKA				TENNESSEE			
BMINGHAM	129	2580	2824	BOISE	524	5575	5484	GRAND ISLAND	354	5714	6201	BRISTOL	297	3631	4206
HTSVILLE	181	3048	3270	LEWISTON	439	4895	5148	LINCOLN	328	5460	6030	CHATTANOOGA	180	3388	3454
MILE	8	1390	1684	POCATELLO	615	6496	6589	NORFORK	352	6108	6741	KNOXVILLE	203	3396	3431
MTGOMERY	67	2138	2261					NORTH PLATTE	521	6763	6440	MEMPHIS	100	2572	3205
				ILLINOIS				OMAHA	261	5166	5881	NASHVILLE	183	3060	3651
ALASKA				CAIRO U	184	3247	3795	SCOTTSBLUFF	469	5907	6403	OAK RIDGE	262	3835	3867
A.HORAGE	897	10168	10016	CHICAGO O HARE	411	5358	6212	VALENTINE	485	6607	6954				
METTF	610	6328	6251	CHICAGO MIDWAY	405	5305	5893					TEXAS			
R.ROW	2014	19529	17882	MOLINE	385	5518	6191	NEVADA				ABILENE	66	2389	2599
B.TER ISLAND	1867	19196	17706	PEORIA	351	5427	5901	ELKO	701	6703	6887	AMARILLO	253	3761	4092
BIHEL	1427	13319	12029	ROCKFORD	473	6234	6577	ELY	749	7025	7103	AUSTIN	19	1462	1737

Figure 8.--*Sample of* Climatological Data, National Summary *sheet for heating degree days.*

HOURLY PRECIPITATION

HOURLY AMOUNTS

MICHIGAN
MARCH 1975

STATION	DATE	A.M. Hour Ending 1	2	3	4	5	6	7	8	9	10	11	12	P.M. Hour Ending 1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
ULT STE MARIE WSO AP //	6	.02		.01	.01																					.04
	7																				.01					.01
	12		.02	.04	.04	.07	.04	.01	.03	.05	.02	.01	.01				.03	.01								.38
	13		.03	.01	.01																					.05
	19										.01															.01
	22			.01	.03	.01	.04	.02	.01	.01																.13
	24		.01	.10	.03	.09	.10	.08	.08	.14	.06	.10	.04	.10	.02	.02	.01					.02		.01		1.01
	25		.02	.02	.06	.02	.01	.01	.01																	.15
	28																					.01	.01	.01	.04	.07
	29	.03	.03	.03	.04	.02	.03	.03	.01		.01									.01	.01				.01	.26
	30				.01													.01	.01							.03
SEBEWAING MICH SGR CO	5																			.01	.09	.03	.02			.15
	7	.01	.03	.01			.02	.03	.02	.03		.02	.02		.01											.20
	8				.02																					.02
	12		.02	.02	.01	.01	.04			.02	.03															.15
	22					.04	.15	.06	.04																	.29
	23																								.02	.02
	24	.03	.08	.05	.02	.01	.02	.10	.05																	.36
	25								.02		.01					.01										.04
	28																		.03	.01					.05	.09
	29	.05			.02	.01																				.08

MONTHLY MAXIMUM AMOUNTS

(Apply heading as appropriate)

	HOURS	1	2	3	6	12	24	ACCUMULATION
	MINUTES	15	30	45	60	120	180	
ULT STE MARIE WSO AP	AMOUNT	.14	.22	.30	.56	.94	1.02	
	DATE/TIME OF ENDING	24/9:00A	24/9:00A	24/11:00A*	24/11:00A	24/2:00P	25/2:00A	
SEBEWAING MICH SGR CO	AMOUNT	.15	.21	.25	.29	.38	.38	
	DATE/TIME OF ENDING	22/6:00A	22/7:00A	22/8:00A*	22/8:00A	24/8:00A	24/8:00A	

Figure 9.--*Sample of* Hourly Precipitation Data.

Storage-Gage Precipitation Data for Western United States

This is another specialized NOAA issue, reeased annually. It utilizes stations eqipped with storage precipitation gages tcpresent precipitation data from remote aras in the West.

Snow Cover Survey

Another single-element document, *Snow Coer Survey*, presents data on snow depths and water equivalents for December through April. The area covered by this NOAA report includes more than 700 stations in New York State and New England plus a few stations in Pennsylvania.

Westside Mountain Weather and Avalanche Network

The *Westside Mountain Weather and Avalanche Network* monitors 40 stations that gather data for snow and avalanche research.

The stations, located in seven Northwestern States and Alaska, record maximum, minimum, ambient, and snow temperatures, snow depth and water equivalent, and wind direction and speed. The data collected on avalanche occurrence include type, size, vertical fall distance, and other important features. The observation period is December through April with most stations' records beginning in 1968 and a few in 1950. Data are available from the Rocky Mountain Forest Experiment Station, USDA Forest Service, 240 W. Prospect Street, Fort Collins, Colorado 80521.

Water Supply Outlook

The USDA Soil Conservation Service (SCS) provides leadership for a Federal-State-Private Snow Survey Program in the mountainous western States. The program concentrates on snow depth (fig. 10) and snow water equivalence although precipitation and soil moisture, and soil and air temperature are also measured at some of the 1,600 observation sites. The information is used primarily to forecast spring and summer streamflow. Data are published throughout the late winter and spring for 11 States as individual State bulletins of *Water Supply Outlook*. *Western U.S. Water Supply Outlook* is also issued in February, March, April, and May. Published snow depth and water equivalent data are available from Western SCS offices by contacting the snow survey supervisor in the State of interest.

Weekly Weather & Crop Report

Seven-day charts of total precipitation and departures of average temperature across the country can be found in the *Weekly Weather and Crop Report*, a joint NOAA and USDA publication. This periodical is especially valuable to agriculturalists because it briefly summarizes the week's weather and its effects on crops State by State. A total growing degree day chart (fig. 11), a chart of the Palmer Drought Index (fig. 12), and another of the Crop Moisture Index, a derivation of the Palmer Index, are also included during the crop season. During the winter each issue presents a national, current chart of depth of snow on the ground. Other charts of

SNOW ABOUT FEBRUARY 1, 1976

DRAINAGE BASIN and/or SNOW COURSE		THIS YEAR			PAST RECORD Water Content (Inches)	
NAME	Elevation	Date of Survey	Snow Depth (Inches)	Water Content (Inches)	Last Year	Average †
SALT RIVER						
Baldy *	9125	1/29	21	5.4	3.8	5.7
Beaver Head	8000	1/30	6	1.4	2.8	3.1
Canyon Creek	7500	1/30	9	3.1	2.1	3.1
Canyon Point	7600	1/30	8	3.1	2.0	3.3**
Coronado Trail	8000	1/30	1	0.3	1.6	2.9
Forest Dale	6430	1/30	3	1.2	0.5	1.1
Ft. Apache	9160	1/29	22	6.0	5.1	6.0
Hannagan Meadows	9090	1/30	21	5.2	4.8	7.0**
Hawley Lake	8300	1/30	21	5.3	4.4	5.8**
Heber	7600	1/30	7	2.5	1.9	3.2
Maverick Fork	9050	1/29	27	5.8	4.3	6.9
McNary	7200	1/30	6	1.8	1.4	2.1
Milk Ranch	7000	1/30	1	0.2	0.6	1.5
Mt. Ord (A)	11000	NO SURVEY			---	17.0**
Nutrioso *	8500	1/30	3	1.1	1.9	2.1
Promontory Butte	7930	1/30	23	7.3	5.6	---
Smith Cienega (A)	9850	NO SURVEY			---	---
Sunrise Summit	10600	1/29	27	7.7	8.1	---
Wilson Lake	9000	1/29	26	5.9	5.2	7.8**
Workman Creek	6900	1/28	16	5.4	2.5	4.9

Figure 10.--*Sample of* Water Supply Outlook.

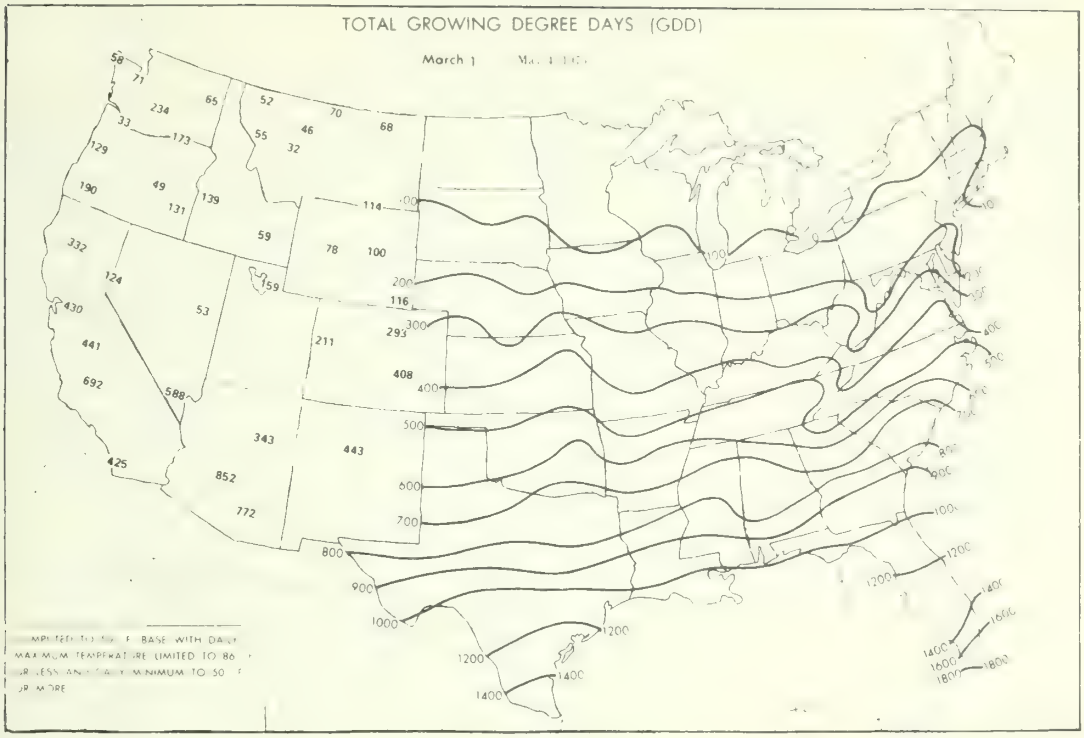

Figure 11.--*Sample of* Weekly Weather and Crop Report's *total growing degree day chart.*

ating degree day accumulation and per-
ent possible sunshine are also included
ig. 13).

Storm Data

Storm Data, a monthly NOAA publication, presents a chronological State listing of occurrence of storms and unusual weather phenomena together with data on the paths of individual storms, deaths, injuries, and resulting property damage.

Daily Weather Maps (Weekly Series)

The NOAA *Daily Weather Maps (Weekly Series)* include a surface weather map (analysis for 7:00 a.m. e.s.t.), the 500-millibar height contours chart, the highest and lowest temperature chart, and a precipitation areas and amounts chart. All maps for each day are arranged on a single page and are copied from operational weather maps prepared at the National Meteorological Center of the National Weather Service. Forms of the *Daily Weather Map* are available from 1878.

Synoptic Series, Daily Weather Maps, Northern Hemisphere Sea Level & 500-Millibar Maps & Data Tabulations

This series comprises two separate publications; one presents the Northern Hemisphere maps (monthly), and the other contains the data tabulations (daily). The series begins with data for January 1899, but until July 1955 both the maps and the data tabulations were published monthly. From the beginning of the series through January 1964, both Part I and Part II were in printed form. In January 1964 printing of Part II was replaced by 35-mm microfilm or microfiche available from the National Climatic Center.

Part I.--Northern Hemisphere Sea Level Charts and 500-Millibar Charts is a series of daily synoptic weather maps. Each volume consists of Northern Hemisphere maps for 1 month comprising one sea level map and one upper air constant pressure surface map for each day from data observed at 12:00 G.m.t.

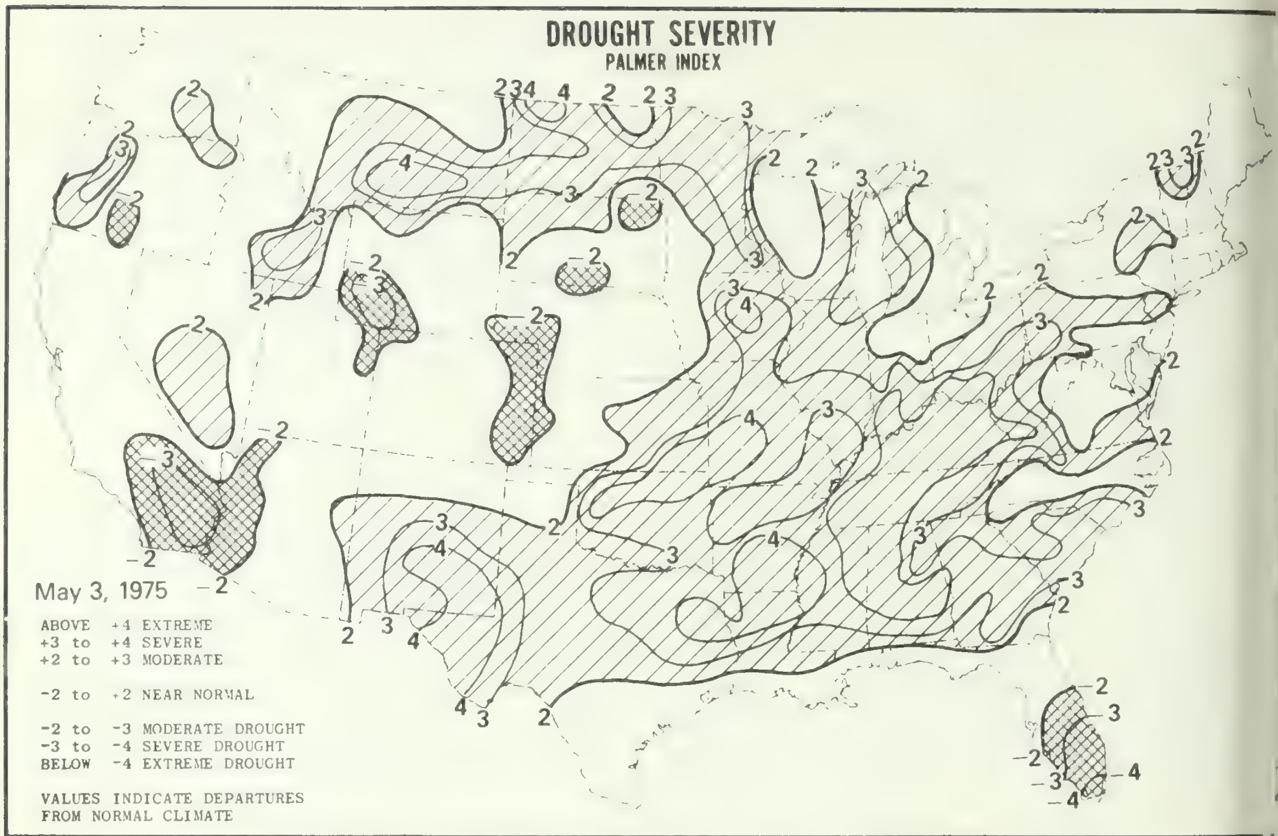

Figure 12.--*Sample of* Weekly Weather and Crop Report's *chart of the Palmer Drought Index.*

Part II.--Northern Hemisphere Data Tabulations is issued daily and contains synoptic surface and upper air reports. Sea level data are presented in two sections, one for land, the other for marine reports. Upper air information includes rawinsonde and upper wind reports.

Atmospheric Turbidity and Precipitation Chemistry Data

Atmospheric Turbidity and Precipitation Chemistry Data is a joint publication of the World Meteorological Organization (WMO), the Environmental Protection Agency, and NOAA. It is prepared annually from records submitted by stations in the WMO network for monitoring background air pollution. Forty United States sites are included in the turbidity measurement network and 19 in the precipitation chemistry network.

Precipitation chemistry tables include information for 22 atmospheric pollutants. The network hopes to identify long-term trends in the concentration of significant constituents in the atmosphere that may affect the environment sufficiently to induce climatic changes.

CLIMATIC SUMMARIES

A tremendous volume of climatic data exists that includes means, extremes, probabilities, etc. Climatological summaries that depict the climate of a geographic area in terms of the distribution and variation of weather elements have many uses For some studies it is more important to know the climate of a certain region, State, or research area than to know the weather on a particular day. The climatic summaries are computed over a long time period; 30 years is the usual standard. Some of the better known and most valuable climatic sources follow.

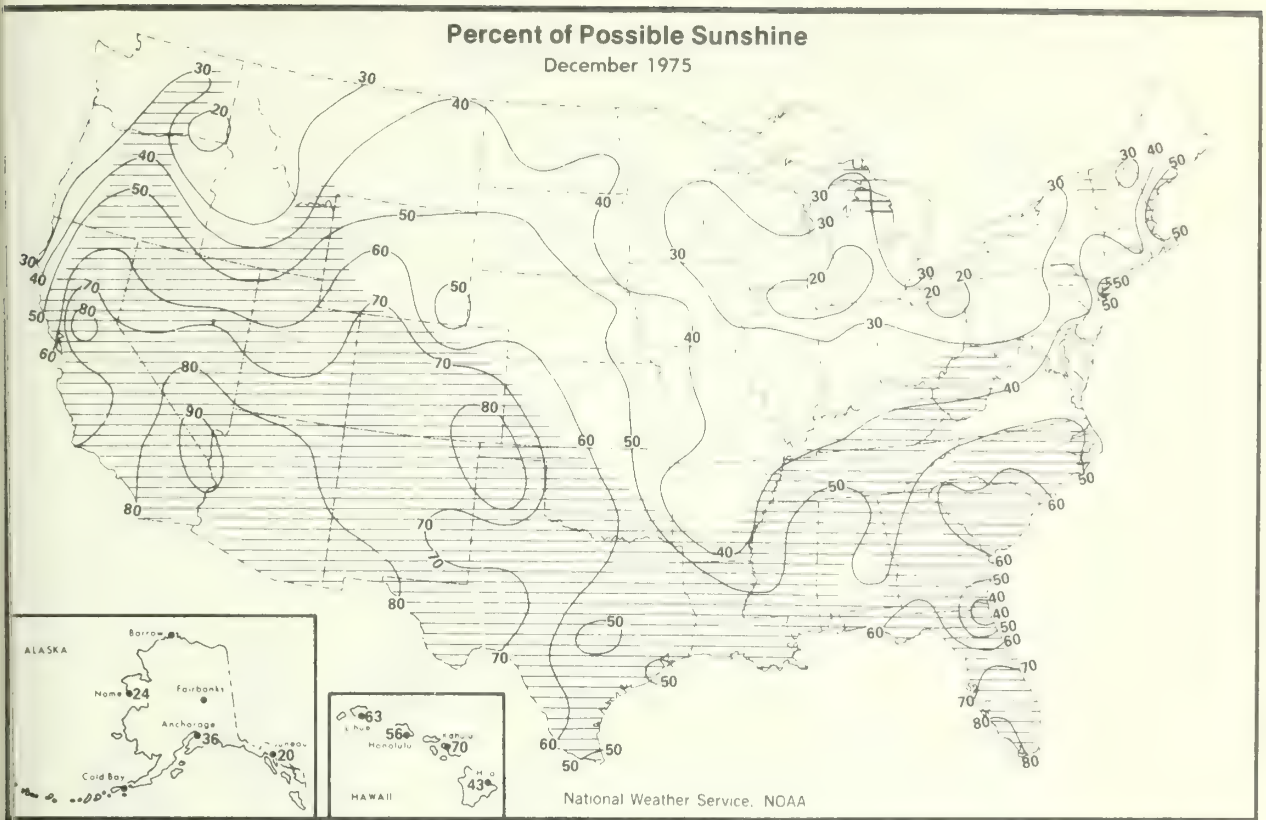

Figure 13.--*Sample of* Weekly Weather and Crop Report's *chart of percent possible sunshine.*

Climate and Man

Many offices still rely on the 1941 Yearbook of Agriculture, *Climate and Man,* as a reference document. It contains everything from a discussion of climate as a world influence, to climatic influence on agricultural settlement and the farmer, to climatic summaries of the individual States. The book was outstanding for its day, but should be used with caution because some of the data have been superseded.

Climatic Atlas of the United States

The *Climatic Atlas of the United States* published by NOAA is a more accurate series of climatic maps than the book *Climate and Man.* It presents the national distribution of mean, normal, and/or extreme values of precipitation (fig. 14), temperature, wind, barometric pressure, relative humidity, dewpoint, sunshine, sky cover, heating degree days, solar radiation, and evaporation. In all, there are 271 climatic maps and 15 tables. The map projection has been standardized to allow easy comparison and correlation of the various climatic elements and their patterns.

Climatological Substation Summaries (Plus Other Local Summaries)

Climatological, tabular summaries are available for many locations, including the more than 300, first-order stations of NOAA (issued as *Local Climatological Data - Annual Summary*). In addition, there are more than 1,200 *Climatological Substation Summaries* and smaller collections of data bases concentrating on resort centers and cities. A collection of summaries by the USDA Soil Conservation Service contains a section on local climate. All data sets are available from the National Climatic Center in Asheville. Differences exist in data presentation, but all within-group categories have standardized formats. For example, the *Climatological Substation Summary* presents a "means and extremes" table for temperature and precipitation for a 30-year period (fig. 15). It also includes tables of monthly and annual average temperature and total

NORMAL MONTHLY TOTAL PRECIPITATION (Inches) WESTERN UNITED STATES
For Selected Stations

Based on 30-year Period, 1931-60

Figure 14.--*Sample of* Climatic Atlas of the United States.

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
ENVIRONMENTAL DATA SERVICE
IN COOPERATION WITH MICHIGAN WEATHER SERVICE

CLIMATOGRAPHY OF THE UNITED STATES NO. 20 - 20

LATITUDE 44° 37'
LONGITUDE 83° 25'
ELEV (GROUND) 675 Feet

CLIMATOLOGICAL SUMMARY

Revised December 1971

STATION HARRISVILLE, MICHIGAN
ALCONA COUNTY

MEANS AND EXTREMES FOR PERIOD 1940-1969

Month	Temperature (°F) Means: Daily maximum	Means: Daily minimum	Means: Monthly	Extremes: Record highest	Year	Record lowest	Year	Mean degree days *	Precipitation Totals (Inches): Mean	Greatest daily	Year	Snow, Ice Pellets: Mean	Maximum monthly	Year	Greatest daily	Year	Mean number of days: Precip. .10 inch or more	Temperatures Max.: 90° and above	Max.: 32° and below	Min.: 32° and below	Min.: 0° and below	Month
(a)	30	30	30	30		30		30	30	30		30	30		30		30	30	30	30	30	
JANUARY	28.8	12.6	20.7	56	1940	-24	1968	1373	1.74	1.51	1940	15.9	35.5	1951	11.0	1947	5	0	19	31	6	JANUARY
FEBRUARY	30.9	12.9	21.9	53	1954	-24	1959	1218	1.58	1.90	1950	14.5	38.7	1950	13.0	1950	5	0	16	28	4	FEBRUARY
MARCH	38.1	19.8	29.0	78	1945	-21	1962	1116	1.93	1.57	1947	11.3	26.4	1952	12.0	1947	5	0	9	28	2	MARCH
APRIL	51.8	31.0	41.4	88	1962	3	1954	708	2.44	2.16	1952	2.0	12.5	1952	8.0	1952	6	0	*	18	0	APRIL
MAY	63.0	39.2	51.1	92	1962+	19	1966	434	3.06	2.53	1955	.1	3.0	1961	1.5	1961	7	*	0	7	0	MAY
JUNE	73.6	50.0	61.8	98	1964	25	1946	132	2.75	1.70	1943	0	0		0		7	2	0	*	0	JUNE
JULY	78.3	55.4	66.9	100	1966	33	1965	53	2.79	3.06	1951	0	0		0		6	2	0	0	0	JULY
AUGUST	77.3	54.9	66.1	102	1948	33	1965	65	3.00	2.03	1968	0	0		0		6	2	0	0	0	AUGUST
SEPTEMBER	69.9	48.2	59.1	100	1953	25	1965	195	3.00	2.03	1947	0	0		0		7	*	0	1	0	SEPTEMBER
OCTOBER	60.1	39.3	49.7	88	1963	15	1969	477	2.24	1.95	1969	.2	2.7	1952	1.5	1952	5	0	0	8	0	OCTOBER
NOVEMBER	44.8	28.9	36.9	78	1950	- 3	1950	843	2.40	1.97	1944	5.0	30.5	1951	8.4	1944	6	0	3	20	*	NOVEMBER
DECEMBER	32.9	18.2	25.6	61	1965	-18	1968	1221	1.85	1.82	1942	12.2	32.5	1951	7.5	1955+	6	0	15	29	2	DECEMBER
Year	54.1	34.2	44.2	102	Aug. 1948	-24	Jan. 1968+	7835	28.78	3.06	July 1951	61.2	38.7	Feb. 1950	13.0	Feb. 1950	71	6	62	170	14	Year

Figure 15.--*Sample of means and extremes table for temperature and precipitation for a 30-year period from* Climatological Substation Summary.

recipitation, a narrative summary of the tation climate, and a history of changes n its location, exposure of instruments, nd related information (fig. 16). Other roupings, such as the first-order stations, ollow much the same format but may inlude other details.

World Wide Airfield Climatic Data

The *World Wide Airfield Climatic Data* ummaries were prepared by the Environmental echnical Applications Center, Air Weather ervice, U.S. Air Force, and were made vailable to the U.S. Navy on magnetic tape or compilation in book form. The series onsists of climatological summaries for bout 3,000 airfields or the climatic areas n which they are located. Copies may be btained from the Federal Clearing House or Scientific and Technical Information, pringfield, Virginia 22151.

Weather Bureau Technical Papers

Between 1943 and 1965 NOAA issued 55 limatic summaries called *Weather Bureau echnical Papers*. Many dealt with precipation extremes with the most ambitious ntitled, *Maximum Station Precipitation for 1, 2, 3, 6, 12, and 24 Hours* (W.B. Technical Paper No. 15). It covers each of the United States and presents maximum observed precipitation amounts for durations of 24 hours or less. A separate table is shown for each station equipped with a recording gage. Each table presents the monthly and annual maximum fall of precipitation over indicated hours together with the dates of occurrence.

Two other issues of this series that deal with precipitation are worthy of special note. Number 25 illustrates rainfall intensity, duration, and frequency curves for selected United States stations and Puerto Rico. Number 40 is a rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return-periods from 1 to 100 years.

The *Weekly Mean Values of Daily Total Solar and Sky Radiation* (W.B. Technical Paper No. 11) presents weekly mean values of daily total solar and sky radiation received on a horizontal surface at 35 NOAA and cooperating stations for up to 35 years of record. Curves were drawn through the plotted data to permit visualization of the annual march of radiation. Photocopies of the publications can be obtained from the National Climatic Center.

Total Precipitation (Inches)

Year	Jan	Feb	Mar.	Apr	May	June	July	Aug.	Sept	Oct.	Nov	Dec	Ann l
[illegible]	2.04	.57	.56	1.42	2.93	3.67	2.47	4.91	3.50	2.55	2.60	1.91	29.13
[illegible]	1.76	.71	.96	2.48	3.45	.90	2.58	2.54	3.85	4.74	3.32	.66	27.95
[illegible]	1.01	.34	2.60	.78	5.90	3.09	2.81	1.95	5.17	1.58	1.41	2.75	29.39
1943	1.56	1.69	3.47	2.37	2.23	3.09	3.49	1.77	2.12	1.73	2.66	.87	27.05
1944	.52	1.10	1.99	1.27	1.46	5.13	2.71	3.11	2.69	.92	4.32	.47	25.69
1945	1.22	.98	.56	1.98	6.09	4.52	2.47	1.07	2.69	3.34	1.96	2.02	29.10
1946	2.47	1.24	.92	.66	2.85	1.64	.95	1.13	2.62	.48	2.48	2.59	20.03
1947	2.06	.91	2.84	3.26	4.39	1.73	2.42	2.74	5.08	.88	1.42	.60	28.33
1948	1.08	1.86	4.14	2.33	2.39	2.86	2.41	.87	1.10	.94	3.01	1.68	24.67
1949	2.97	2.19	1.38	1.67	1.42	3.14	.96	2.48	3.86	1.10	2.37	2.90	26.44
1950	3.95	5.24	3.17	2.55	1.61	3.03	2.82	3.56	4.47	1.95	2.44	2.79	37.58
1951	3.53	3.07	2.34	4.53	1.47	2.35	7.58	3.03	3.55	6.11	3.36	3.47	44.39
1952	4.25	2.25	3.56	4.16	1.59	2.62	6.06	3.72	1.79	.43	2.80	2.82	36.05
1953	2.13	2.38	3.43	2.35	6.35	1.72	4.14	3.45	3.40	1.81	2.17	1.58	34.91
1954	3.18	2.04	2.97	4.24	3.15	4.40	1.24	3.93	2.90	5.69	3.48	2.79	40.01
1955	2.05	2.49	1.97	2.46	4.17	1.02	1.63	3.85	.39	3.05	1.92	2.06	27.06
1956	.60	1.55	1.77	3.19	2.50	1.75	2.89	4.85	1.56	.54	1.52	1.60	24.32
1957	1.07	.63	1.42	3.13	2.34	4.60	4.19	1.35	2.71	2.83	2.52	1.86	28.65
1958	1.62	1.12	.58	1.21	.91	2.24	2.63	1.93	2.56	2.87	2.72	.73	21.12
1959	1.27	2.23	2.44	5.10	3.31	.78	3.27	4.88	4.13	3.97	3.71	3.44	38.53
1960	1.59	2.06	1.26	2.39	4.47	3.00	3.15	1.68	2.06	1.43	2.30	.60	25.99
1961	.20	2.07	3.34	1.75	1.49	2.85	2.22	2.49	4.80	..81	2.35	1.05	25.42
1962	1.90	2.20	1.05	1.55	3.80	4.55	2.10	2.50	2.99	2.27	1.15	1.65	27.71
1963	1.00	.65	2.28	2.20	5.40	1.40	4.50	3.65	1.75	.80	1.50	1.80	26.93
1964	1.00	.30	1.80	2.85	2.35	1.12	4.20	3.75	2.74	1.05	3.10	2.35	26.61
1965	2.40	2.75	1.60	2.47	3.26	1.71	1.89	5.42	6.43	1.84	1.87	2.05	33.69
1966	.75	.49	2.19	1.32	.93	1.76	1.36	3.18	1.30	1.76	3.42	1.70	20.16
1967	.91	.74	.60	3.58	1.91	4.66	1.16	3.35	2.26	3.01	1.67	2.20	26.05
1968	.71	1.13	.19	2.21	4.40	3.78	1.85	5.52	3.38	2.08	1.83	1.41	28.49
1969	1.54	.48	.66	1.87	3.18	3.43	1.48	1.14	1.90	4.64	.48	1.09	21.89

STATION HISTORY

Weather records were taken in Harrisville for a short time in 1879. Observations began again in 1888 and continued until 1923 with instruments installed at a boathouse but exact location in unknown. In 1924, the station was moved to the State Fish Hatchery, 2 blocks south of the Harrisville Post Office and remained there until 1946. In 1947, it was moved to a location 1.2 miles north of the post office and in 1955, to the City Waterworks, 0.5 mile west northwest of the post office. On October 5, 1961, the station was moved to 6 blocks west of the post office and again moved to a site 6.8 miles southwest of the post office on April 27, 1965.

Figure 16.--*Sample of monthly and annual precipitation table from Climatological Substation Summary.*

Summary of Hourly Observations

NOAA published a *Summary of Hourly Observations (1951 to 1960)* for all first-order stations that recorded 24-hourly observations. It is the most comprehensive tabulation of hourly data available. The information is based on hourly observations listed in *Local Climatological Data Supplements,* a monthly publication since replaced by publication of 3-hour observations shown on the reverse side of *Local Climatological Data* (fig. 4). The somewhat complex tables in the 10-year summary give such things as frequency of occurrence of precipitation amounts for each hour of the day, and categories of temperature and wind speed-relative humidity occurrences for each station.

Heating Degree Day Normals, Monthly Normals of Temperature, Precipitation, and Heating Degree Days (Also Daily)

Three limited-use climatic summaries are also worthy of mention. *Heating Degree Day Normals* are available for all first-order NOAA stations and all cooperators who have data archived for a full 30 years. These monthly and annual normals of heating degree days (base 65°F) are grouped by State. A more elaborate NOAA tabulation is available in *Monthly Normals of Temperature, Precipitation, and Heating Degree Days.* It was issued for each State or combination of States and contains the normal values of monthly and annual maximum, minimum, and average temperature, precipitation, and heating degree days. *Daily Normals of Temperature and Heating Degree Days* for a select series of first-order stations have also been assembled by the National Climatic Center.

HISTORIC DATA

Meteorology has more archived usable physical data than any other science. Moreover, the data gathered a century ago were

s good as those taken today. If the need oes arise for 50- or 150-year-old weather ata, they are available from the National limatic Center.

FOR MORE INFORMATION

This guide is not intended to be a omplete reference to all weather and cliate data bases and summaries. The best atalog of atmospheric data for those who eed more detailed or exotic materials is ntitled *Selective Guide to Climatic Data ources, Key to Meteorological Records ocumentation No. 4.11*. It expands upon he contents of many of the publication escriptions presented in this report. The ublication refers primarily to published limatological data. This NOAA document is ow out of print but is available in most ood climatological libraries. There is lso a wealth of unpublished climatological ummaries available in the files of the ational Climatic Center. An index to these ummaries is given in the *Guide to Standard eather Summaries, NAVAIR 50-1C-534*.

For more information on the national ollection of weather data and its reposiry, NOAA issued a 35-page booklet, *The tional Climatic Center*. This is availle upon request from the Center.

Formats, archiving, and retrieval produres for fire-weather observations are mmarized in *The National Fire Weather ta Library: What It Is and How to Use* . This is a USDA Forest Service General chnical Report (RM-19) by R. W. Furman d G. E. Brink.

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APPENDIX.--STATUS OF THE CLIMATOLOGICAL PROGRAM IN EACH STATE (1976)

The organization and location in the list below indicates the recipient of currnt climatological data. If a second orgnization is noted (#), it is the holder o the State's climatological files and lbrary, otherwise the first indicated orgnization fulfills both functions. Current adresses and telephone numbers of the orgnization can be obtained at the NOAA, Ntional Weather Servie Office nearest the otanization's location. The status of srvice is given by the following categories:

A. Receives and files current records. Provides full public service.

B. Receives and files current records. Provides limited public service.

C. Receives and files current records. Offers no public service although materials are generally available for research.

D. Receives and files all current records. Offers no public service.

State	*Organization*	*Location*	*Status*
Alabama	Auburn U.	Auburn, Alabama	C
Alaska	Arctic Environmental Information & Data Center	Anchorage, Alaska	A
Arizona	Arizona State U.	Tempe, Arizona	A
Arkansas	NOAA	Little Rock, Arkansas	D
	#Individual NOAA Offices		
California			
Northern	NOAA	Sacramento, California	A
(Some services also provided by California Department of Water Resources, Sacramento).			
Southern	NOAA	Los Angeles, California	A
Colorado	Colorado State U.	Fort Collins, Colorado	A
Connecticut	Mr. R. E. Lautzenheiser	35 Arcadia Ave. Reading, Massachusetts 01867	B
	#Univ. of Connecticut		
Delaware	NOAA	Baltimore, Maryland	C
(Some information filed at Univ. of Maryland, College Park, Maryland).			
Florida	Auburn Univ.	Auburn, Alabama	C
Georgia	Auburn Univ.	Auburn, Alabama	C
Hawaii	NOAA	Honolulu, Hawaii	C
	#Univ. of Hawaii	Honolulu, Hawaii	
Idaho	NOAA	Boise, Idaho	D
	#Individual NOAA Offices		
Illinois	Illinois State Water Survey	Urbana, Illinois	B
Indiana	Purdue Univ.	Lafayette, Indiana	B
Iowa	NOAA	Des Moines, Iowa	D
	#Iowa Weather Service	Des Moines, Iowa	
Kansas	Kansas State Univ.	Manhatten, Kansas	B
Kentucky	NOAA	Lexington, Kentucky	D
	#Individual NOAA Offices		
Louisiana	Louisiana State Univ.	Baton Rouge, Louisiana	B
Maine	Mr. R. E. Lautzenheiser	35 Arcadia Ave. Reading, Massachusetts 01867	B
	#Individual NOAA Offices		
Maryland	NOAA	Baltimore, Maryland	B
	#Univ. of Maryland	College Park, Maryland	
Massachusetts	Mr. R. E. Lautzenheiser	35 Arcadia Ave. Reading, Massachusetts 01867	A
Michigan	Mich. Dept. of Agriculture	E. Lansing, Michigan	A
Minnesota	Univ. of Minn.	St. Paul, Minnesota	A
Mississippi	NOAA	Jackson, Mississippi	D
	#Individual NOAA Offices		
Missouri	Univ. of Missouri	Columbia, Missouri	B
Montana	Montana State Univ.	Bozeman, Montana	C
Nebraska	Univ. of Nebraska	Lincoln, Nebraska	B
Nevada	NOAA	Reno, Nevada	C
	#Univ. of Nevada	Reno, Nevada	
New Hampshire	Mr. R. E. Lautzenheiser	35 Arcadia Ave. Reading, Massachusetts 01867	B
	#Individual NOAA Offices		
New Jersey	Cook College, Rutgers Univ.	New Brunswick, New Jersey	C
New Mexico	NOAA	Albuquerque, New Mexico	D
	#Individual NOAA Offices		
New York	Cornell University	Ithaca, New York	A
North Carolina	NOAA	Raleigh, North Carolina	D
	#Individual NOAA Offices		
North Dakota	North Dakota State Univ.	Fargo, North Dakota	B
Ohio	NOAA	Columbus, Ohio	B
	#Ohio State Univ.	Columbus, Ohio	

State	*Organization*	*Location*	*Status*
Oklahoma	NOAA #Univ. of Oklahoma	Oklahoma City, Oklahoma Norman, Oklahoma	B
Oregon	NOAA #Oregon State University	Portland, Oregon Corvallis, Oregon	C
Pennsylvania	NOAA #NOAA	Allentown, Pennsylvania Harrisburg, Pennsylvania	D
Rhode Island	Mr. R. E. Lautzenheiser #Individual NOAA Offices	35 Arcadia Ave. Reading, Massachusetts 01867	B
South Carolina	NOAA #Clemson Univ.	West Columbia, South Carolina	C
South Dakota	S. Dakota State Univ.	Brookings, South Dakota	B
Tennessee	NOAA #Univ. of Tennessee	Old Hickory, Tennessee Knoxville, Tennessee	C
Texas	Texas A & M Univ.	College Station, Texas	A
Utah	Utah State Univ.	Logan, Utah	A
Vermont	Mr. R. E. Lautzenheiser #Individual NOAA Offices	35 Arcadia Ave. Reading, Massachusetts 01867	B
Virginia	NOAA #Virginia Polytechnic Institute	Baltimore, Maryland Blacksburg, Virginia	C
Washington	NOAA	Seattle, Washington	C
West Virginia	W. Virginia Univ. #NOAA	Morgantown, West Virginia Charleston, West Virginia	B
Wisconsin	Univ. of Wisconsin	Madison, Wisconsin	A
Wyoming	Univ. of Wyoming #Individual NOAA Offices	Laramie, Wyoming	C
Puerto Rico	NOAA #Individual NOAA Offices	San Juan, Puerto Rico	D

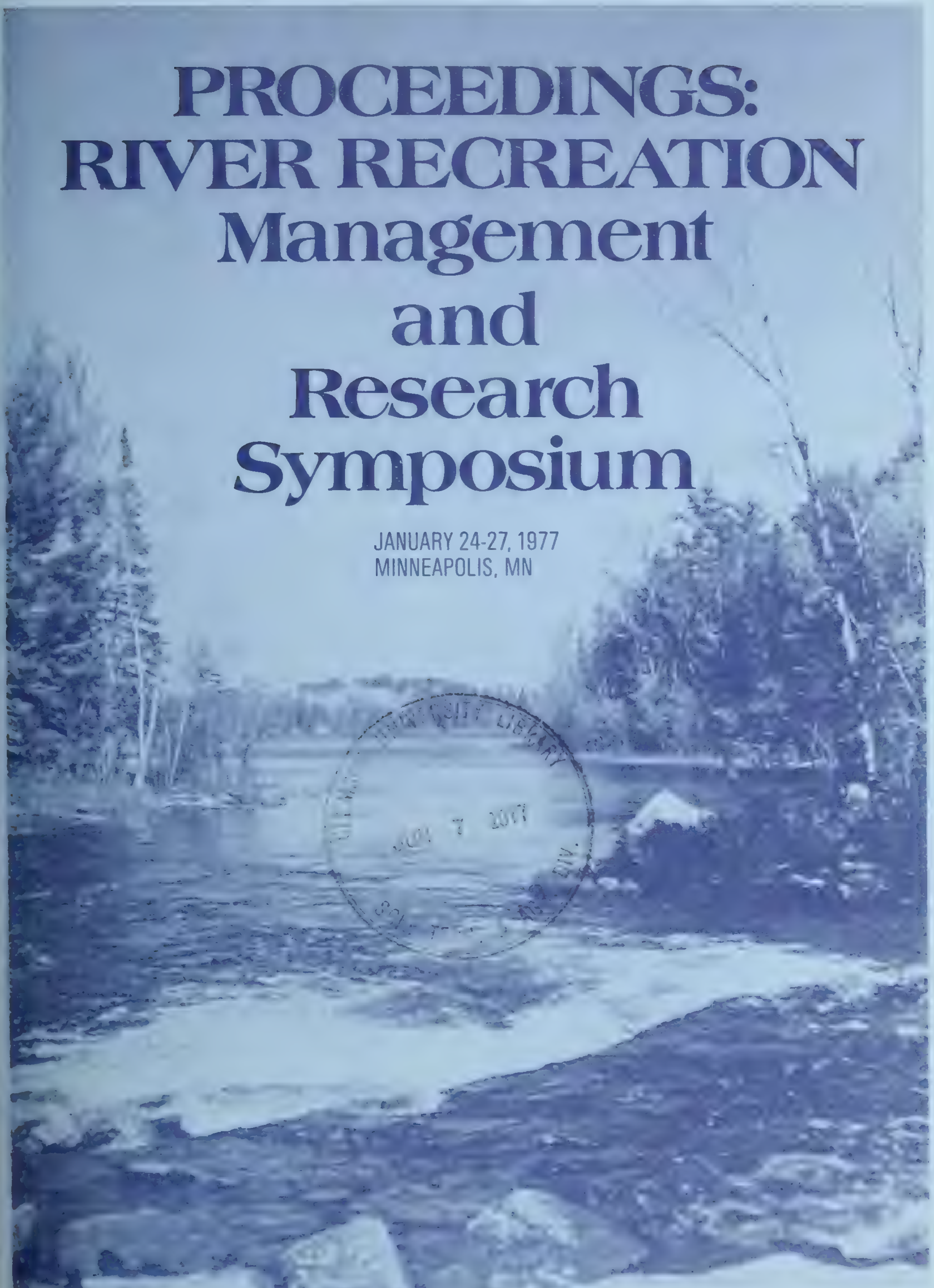
U.S. Government Printing Office: 1977—766-553/65 Region No. 6

Shhhh...noise pollutes too!

USDA FOREST SERVICE
GENERAL TECHNICAL REPORT NC-28

PROCEEDINGS: RIVER RECREATION Management and Research Symposium

JANUARY 24-27, 1977
MINNEAPOLIS, MN



NORTH CENTRAL FOREST EXPERIMENT STATION
FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

North Central Forest Experiment Station
John H. Ohman, Director
Forest Service - U.S. Department of Agriculture
1992 Folwell Avenue
St. Paul, Minnesota 55108

1977

PROCEEDINGS

Symposium

RIVER RECREATION MANAGEMENT and RESEARCH

January 24-27, 1977

Minneapolis, Minnesota

Sponsored by:

North Central Forest Experiment Station
Backcountry River Recreation Management Research Project

Co-Sponsored by:

University of Minnesota, College of Forestry

Northeastern Area, State & Private Forestry,
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Interagency Whitewater Committee

Bureau of Land Management, U.S. Department of Interior

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Tennessee Valley Authority

U.S. Army Corps of Engineers, Department of Army

National Park Service, U.S. Department of Interior

Bureau of Outdoor Recreation, U.S. Department of Interior

Office of Water Research and Technology
U.S. Department of Interior

FOREWORD

The first national symposium on river recreation management and research was held January 24-27, 1977 in Minneapolis, Minnesota. The purpose of the Symposium was to encourage and stimulate the exchange of ideas, problem solutions, and research needs within this rather broad field. To do this, we sought to assemble key representatives of the various groups concerned with river recreation--river planners and managers, public agency administrators, researchers, students, private entrepreneurs, representatives from outdoor recreation and conservation organizations, and private citizens. A key part of the Symposium was the discussion (formal and informal) generated among these people.

The timeliness of this Symposium attracted nearly 400 participants from 44 States and 5 Canadian Provinces, representing all of the groups concerned with river recreation noted above. This diversity among participants (geographically as well as professionally) and the open and enthusiastic dialogue during the 4-day gathering attested to the intense interest in river recreation management and research activities. The significance of the Symposium was further illustrated by a telegram from Senator Frank Church, of Idaho, author of the Wild and Scenic Rivers Act of 1968, "...I am deeply aware of the need for research and scientific debate to develop the best inventory and management techniques to insure protection of our nations river resources. Your efforts this week in bringing together distinguished scientists and agency managers is a significant step toward that goal."

The Symposium was conceived by the Backcountry River Recreation Management Research Project of the North Central Forest Experiment Station. Social scientists here are embarking on a broad new program of research focusing on the study of human behavior under a variety of river settings and conditions. Because the mission is to carry out such research nationwide, we were challenged by the scope and complexity of the assignment and realized that the Forest Service is only one of many management and research organizations involved in these activities. So, as background for beginning our research, we sought through the Symposium to review recent river recreation management and research accomplishments and to identify research problems and priorities, both social and environmental, that need to be solved.

The formal activities of the Symposium were divided into four General Sessions (23 papers presented orally) which all participants attended, and three Workshop Sessions (9 papers presented orally) each consisting of three concurrent workshops which participants attended according to their interests. Ten informal evening discussions were also held on a variety of timely subjects, such as urban river recreation planning, river safety, and managing river use in desert environments.

Papers by General Session and Workshop speakers along with 23 contributed papers not presented were printed in a preliminary proceedings and mailed to registrants 2 weeks before the Symposium for study.

The 65 papers herein are arranged according to the general format of the Symposium. There are four topics pertinent to river recreation management and research activities that contain 32 papers presented in General Sessions and Workshops. These are followed by 23 contributed papers on a variety of subjects. Next are the summary papers of the nine workshops and of the Symposium in general. Following these is a list of literature cited in all the papers. Finally, there is a list of Symposium participants.

The papers in this Proceedings represent the most definitive state-of-the-knowledge currently available concerning river recreation activity. As such, they should serve as an important collection of reference material upon which future research, planning and management, and general dialogue among interested publics can build.

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TABLE OF CONTENTS

Page

THE ROLE OF RIVER RESOURCES IN OUTDOOR RECREATION

River recreation: history and future 2
Roderick Nash

Some legal aspects of river recreation management in the East 8
Eric J. Curtis

Urban rivers as recreation resources. 19
Clare A. Gunn

Problems resulting from the increased recreational use of rivers in the West. 27
Darrell E. Lewis and Gary G. Marsh

Legal aspects of river recreation management in the West. 32
Robert M. Simmons

Industry responds to the explosion in river recreation. 38
Verne Huser

EVALUATING RIVER RECREATION USE

River landscape quality and its assessment. 46
R. Burton Litton, Jr.

Impacts of river recreation use on streambank soils and vegetation--state-of-the-knowledge. 55
Carl D. Settergren

Economic evaluation of alternative uses of rivers 60
David A. King

Density, crowding, and satisfaction: sociological studies for determining carrying capacities 67
Thomas A. Heberlein

Methods for counting river recreation users 77
Leo F. Marnell

River recreation potential assessment: a progress report 83
Michael Chubb

Alternative strategies for studying river recreationists. 91
Roger N. Clark

MANAGING RIVER RECREATION USE

Management response to growing pressures in western white-water rivers--the art of the possible .102
Kenneth R. Mak, Marvin O. Jensen, and Thomas L. Hartman

Experiences in managing river recreation and river use in Michigan. 110
Harry A. Doehne

Allagash wilderness waterway. 117
Thomas J. Cieslinski

Canoeing use of Huron-Clinton Metropark 121
Robert L. Bryan

Getting your story across--interpreting the river resource. 125
Anne Harrison

TVA'S role in river-oriented recreation 139
J. Harry Lewis

Recreation management planning for a multi-use scenic river corridor. 142
James R. Branch and Stephen C. Fay

Problems and conflicts associated with river recreation programming and management in the East 147
Michael L. Countess, Walter L. Criley, and B. R. Allison

How to ration river floating use: the Middle Fork of the Salmon experience 151
Sam E. Warren

Reducing impacts from river recreation users. 155
William S. Craig

Developing a research capacity in field organizations to aid in management decisionmaking. .163
Kenneth C. Chilman, Leo F. Marnell, and Randall R. Pope

River-running in the Grand Canyon: how much and what kind of use. 168
Joyce McCarl Nielsen and Bo Shelby

River preservation and recreation programs 178
Robert L. Eastman

Managing corridors in multiple ownership 183
James Harrison and Michael F. Priesnitz

FUTURE PERSPECTIVES IN RIVER RECREATION

Regional river recreation management .188
Robert Yearout, Arthur Seamans, and Larry Lee

Information needs for river recreation planning and management 193
Perry J. Brown

Research for river recreation planning and management. 202
David W. Lime

Citizen groups: their role in river recreational planning 210
Claude E. Terry

Commercial river outfitting: its educational role and responsibilities 214
Robert L. Elliott

CONTRIBUTED PAPERS

Some ecological considerations associated with river recreation management. 222
Stewart W. Aitchison, Steven W. Carothers, and R. Roy Johnson

Colorado River campsite inventory. 226
F. Yates Borden, Brian J. Turner, and Charles H. Strauss

New initiatives in heritage preservation: the agreements for recreation and conservation program of Parks Canada. 232
W. F. Cheffins

Visitor employed photography: a tool for interpretive planning on river environments 236
Gabriel J. Cherem and David E. Traweek

Standards of environmental quality for recreational evaluation of rivers. 245
James deBettencourt and George L. Peterson

A survey and analysis of recreational and livestock impact on the riparian zone of the Rio Grande in Big Bend National Park. 256
Robert B. Ditton, David J. Schmidly, William J. Boeer, and Alan R. Graefe

Problems of defining and measuring the preferences of river recreationists 267
B. L. Driver and John R. Bassett

Methods used for evaluating recreational rivers in Canada. 273
Louis Hamill

Recreational usage and users of rivers. 279
Richard D. Hecock

Down by the riverside: informational factors in waterscape preference 285
Rachel Kaplan

A bacteriological analysis of portable toilet effluent at selected beaches along the Colorado River, Grand Canyon National Park, Arizona 290
A. B. Knudsen, R. Johnson, K. Johnson, and N. R. Henderson

Biological approach to river planning and management. 296
James J. Kuska

Simulation modeling as a tool for managing river recreation 304
Stephen F. McCool, David W. Lime, and Dorothy H. Anderson

The complex uses of an accessible river--the Kettle of Minnesota Minnesota 312
L. C. Merriam, Jr. and T. B. Knopp

An attempt to quantify the esthetics of Wild and Scenic Rivers in Idaho. 320
E. L. Michalson

Variation and recreation quality in river management. 329
Thomas A. More, Robert O. Brush, and J. Alan Wagar

Effects of National Park Service and Forest Service
regulations on concession operations. 334
C. R. Michael Parent and Franklin E. Robeson

A Markov-based linear programming model of travel
in the Boundary Waters Canoe Area. 342
George L. Peterson, James S. deBettencourt, and Pai Kang Wang

Campsite choice behavior in the river setting: a
pilot study on the Rogue River, Oregon. 351
Robert E. Pfister

Relations between river trip motives and perception of
crowding, management preference, and experience satisfaction. 359
Joseph W. Roggenbuck and Richard M. Schreyer

Attitudes of Salmon River users toward management
of Wild and Scenic Rivers 365
Don Tarbet, George H. Moeller, and Keven T. McLoughlin

A filter system for determining river suitability
for national Wild and Scenic River status 372
Claude E. Terry

A model for establishing water quality standards
for rivers. 380
Louis R. Waller and Dwight R. McCurdy

SUMMARY PAPERS

Workshop #1--Strategies for counting river recreation users 388
Dorothy H. Anderson

Workshop #2--Classifying river resources as to their
recreation potential. 390
Earl C. Leatherberry

Workshop #3--Strategies for studying river recreation users 393
George L. Peterson

Workshop #4--Rationing river recreation use 397
George H. Stankey

Workshop #5--Methods to control negative impacts of
recreation use. 402
Arthur W. Magill

Workshop #6--Land managers are finding ways to get
research done within their own organizations. 405
Timothy B. Knopp

Workshop #7--Managing river recreation use other
than rationing. 407
Harold K. Cordell

Workshop #8--The future of State and Federal Wild and Scenic River programs 412
John F. Kuhr

Workshop #9--Managing river corridors in multiple ownership 414
George H. Moeller

Symposium summary 417
Robert C. Lucas

LITERATURE CITED. 421

PARTICIPANTS. 437

THE ROLE OF RIVER RESOURCES IN OUTDOOR RECREATION

RIVER RECREATION: HISTORY AND FUTURE

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ABSTRACT.--The recent rise of interest in river recreation must be seen against a background of fear of wild rivers as part of the uncontrolled wilderness. Revolutions in ideas, equipment, and technique paved the way for the transformation of river running from a high-risk expedition to family fun. The future will see increasing competition for the recreational potential of rivers, particularly for float trips. Management must not only determine carrying capacities but devise equitable ways of allocating space to commercial, noncommercial, educational, and other groups under those quotas. The "percentage of disappointment" is one alternative for allocating use. If wilderness values are to be emphasized in management, the noncommercial, do-it-yourself trip involving physical and psychological preparation of each member appears to have higher priority than commercially outfitted and guided "safari" trips.

Time was--and not so long ago in the United States--when rivers had little or nothing to do with recreation. River running, of course, began with the beginnings of the nation and existed before then in the canoeing and kayaking traditions of the first North Americans. Waterways were transportation corridors, highways through country that roads and railroads had not yet made easy of access. Later generations found rivers useful for hydropower, irrigation, sanitation, sewage disposal, and making the morning coffee. But running them for fun was not part of the picture.

Until very recently Americans did not like their water white. Rapids were dreaded and cursed as obstacles to navigation. Well-worn portage trails testified to the determination of early travelers to avoid white water. When money and technology became available, the rapids on key rivers in the transportation network were bypassed by locks or buried under flatwater impoundments. The death of a rapid was reason for celebration, another step in the conquest and transformation of the wilderness of the New World in man's interest. Following the biblical injunction, the crooked had been made straight and the rough place plain.

The recent emergence of rivers as meccas for outdoor recreation can be explained by changes in American attitudes which, in turn, are products of changing environmental circumstances. The ending of the frontier in 1890 is part of that change. So is the shift of American from a predominantly rural to a predominantly urban population, a fact which marked the 1920s. This rise of an urban-industrial civilization fundamentally altered the American conception of wild and natural things. The penthouse perspective was radically different from that of the log cabin. What had been an adversary became a novelty. What had been feared for its solitude became appreciated for the relief it affords from a complex, crowded civilization. What had been hated as dangerous became coveted as challenging. What had been a source of national embarrassment became an object of national pride. Pioneers, in short, were too close to the wild to appreciate it. Ironically, the rise of civilization made possible the appreciation of the wilderness (Nash 1973).

Wild rivers were a beneficiary of this revolution in American thinking. In regard to rivers we can date the changeover in attitude from antipathy (or at least indifference) to affection rather precisely. In 1928 the Swing-Johnson Act authorized the first major dam on the mainstem of the Colorado River. Then called Boulder Dam, but later renamed Hoover, its completion in 1935 was a reason for universal jubilation in the United States. A wild river had been tamed. The engineers were heroes, and as Lake Mead began to fill, a proud nation proclaimed Boulder Dam the eighth wonder of the civilized world.

Thirty years later the tables were almost totally turned. Again engineers proposed a dam on the Colorado River--upstream from Hoover Dam in the Grand Canyon. But this time the engineers did not seem to be the agents of progress that they had in the 1930s. For a great many Americans the Colorado River in the Grand Canyon was not a monster to be shackled and put to work for the economy, but something valuable in its own right and already working to enhance the quality of American life. Reflected in the thousands of letters to Congress and the Lyndon B. Johnson administration, this point of view carried the day. There were enough dams on the Colorado, people said. Let part of the river alone; let it be lonely; dedicate it to backcountry recreation. In 1968 the cheers that 40 years before greeted the authorization of Boulder Dam now sounded in support of the defeat of the Grand Canyon dam projects (Nash 1970). Americans seemed to be saying that rivers had other values besides spinning turbines. It was three centuries in coming, but the day in the sun of public favor for wild rivers finally arrived.

One of the classic ironies in American environmental history is that the kind of public attention that saved the Grand Canyon from being dammed in the 1960s constituted a new threat to rivers--or at least to their wilderness qualities. Having worked to inform Americans about the losses involved in flooding much of the inner Canyon, opponents of the dams watched with alarm as a different kind of flood--a human one--threatened to engulf the river. Statistics in the following tabulation tell a remarkable story:

Travel on the Colorado River Through the Grand Canyon of Arizona

Year	*Number of People*
1867	1[1]
1869-1940	73
1941	4
1942	8
1943	0
1944	0
1945	0
1946	0
1947	4
1948	6
1949	12
1950	7
1951	29
1952	19
1953	31
1954	21
1955	70
1956	55
1957	135
1958	80
1959	120
1960	205
1961	255
1962	372
1963-1964	44[2]
1965	547
1966	1,067
1967	2,099
1968	3,609
1969	6,019
1970	9,935
1971	10,385
1972	16,432
1973	15,219[3]
1974	14,253

[1]*Some contend that James White, a trapper fleeing the Indians, floated the Grand Canyon on a makeshift log raft two years before the famous expedition of John Wesley Powell.*

[2]*Travel on the Colorado River in these years was curtailed by the completion of Glen Canyon Dam upstream and the resultant disruption of flow.*

[3]*The downturn in visitation was the result of the institution by management of a quota system. The numbers applying for the available permits continued to rise sharply.*

By 1972 the possibility of the Colorado River in Grand Canyon being loved to death was very real. The new frontier of river protection was to save the waterways from their friends. Nothing could signal more dramatically the intellectual revolution that between the 1930s and the 1960s transformed the relation of rivers and Americans.

Ideas were not the only change agents in the transformation of river running from the category of a high-risk expedition activity to that of a family vacation. The technique of running white water also changed and improved. Much of the credit here must go to a taciturn Utah trapper named Nathaniel Galloway. In the 1890s Nat Galloway began to run the Colorado and its tributaries. He took the wealthy Columbus, Ohio, industrialist Julius Stone down the Colorado in 1909 in the first commercially-guided, recreationally-motivated river trip in American history. In running rapids Galloway departed from the tradition of John Wesley Powell and previous river explorers by assuming a rowing position facing downstream. From this vantage point Galloway could spot obstacles ahead of his moving boat and, by rowing upstream, slow his pace while "ferrying" left or right. Powell's crew had rowed as if they were on a lake or ocean, facing their wake and rowing so as to increase their speed toward obstacles they could not see. Perfected on the Colorado by the Kolb brothers and Norman Nevills, the Galloway technique greatly increased the river runner's margin of safety.[4]

River boats also improved markedly after 1900. First there were the improved wooden and metal "cataract" boats, but the quantum jump occurred when new materials such as aluminum, fiberglass and neoprend rubber came to the assistance of river travel. Amos Burg pioneered the use of inflatable rubber rafts on the Snake and Colorado Rivers in the 1930s. Then World War II made its contributions to river recreation. From the Pacific theater came the so-called "ten-man" raft used by downed aviators, and used by troops in assaulting the beaches of enemy-held islands. Multichambered, flexible, buoyant, and strong,

---

[4]*Collins, Robert O., and Roderick Nash. 1977. The big drops: ten legendary rapids on rivers of the American West. Oxford Univ. Press. (In press.)*

the 15-foot-long military boats and thei commercially produced imitations proved superb river crafts. Harry Aleson took through the Grand Canyon in 1949. In 19 the legendary "woman of the rivers", Georgie White, tied three "ten-man" raft together to produce a rig with exception stability in big rapids. By this time t Hatch family of Vernal, Utah was also us inflatables for commercial trips on West rivers.[4]

The European theater of World War I also advanced the art of running rivers. As the Germans retreated, burning their bridges behind them, the advancing Allie forces depended on inflatable pontoons t provide temporary bridging. After the w these huge rubber sausages appeared on t surplus market and, shortly thereafter, Western rivers. Georgie White lashed en together to carry 40 people and their eq ment through the Grand Canyon.

Still another factor in the recent boom of river recreation (I am speaking here primarily of multi-day float trips) was the discovery by the public that riv offered a relatively easy way into backcountry. Excluding mechanized transport tion (a tenet of most wilderness legisla tion), how else could you move through 2 miles of roadless country a day without taking a step? Compared to backpacking river travel is a breeze. A magic, flow carpet does the work, carrying the gear that makes camping palatable even to the most fastidious. Of course you have to back to your car--or have it brought to at the end of the run--but on the river is, literally, all downhill. Families w would pale at the thought of a 100-mile backpack, eagerly join a river trip of t same length. I have taken 5-year-olds a people over 80 on major river trips; bli people and paraplegics have run the Gran Canyon. This is, of course, wonderful, but the rivers have become crowded.

The future of river recreation is n hard to discern. The trend is upward. River running is at the take-off point i popularity occupied by downhill skiing i the 1950s. The need of an increasingly civilized people for contact with uncivilized environments will certainly incre Equipment will improve and, in all probability, decrease in cost as a result of mass production. "How-to" books will instruct the novice while guidebooks and

maps will open the last overlooked streams to increased usage. Television specials and documentaries, such as those that made skiing and surfing glamour sports, will whet the public appetite for whitewater. New companies will join those already offering commercial river trips, and the number of do-it-themselvers (many "graduates" of commercial trips) will increase enormously. We are, it would seem, only at the beginning of a trend toward the increased popularity of river recreation.

The pressure this certain popularity will place on management is enormous. One of the first broad decisions that will have to be made, and one that determines the nature of their experience, is the number of people to be permitted to run a given river. The options vary along a wide spectrum. Let's start with "amusement park" rivers. In this case--and we are close to it already on rivers like the Snake in Jackson Hole and the Youghiogheny--management would accept all comers. Find enough water to float your boat and you could run--bumper to bumper. In such a scenario upstream tows, similar to ski lifts, have a place. For the price of a tow ticket a river runner could have his boat hauled upstream for another run of a favorite rapid. He would wait in line, watching other boats run, and then have his 15 seconds of glory. Again the analogy to downhill skiing is compelling. In both situations the attraction is more the run (hill or rapid) than the total environmental setting. Wilderness camping is not a primary interest. On amusement park rivers, as with downhill ski hills, the user wants to get in his runs and retreat to a lodge or condominium. He needs road access and he is not disturbed by crowds except when they make the lift lines too long. He is a white water freak, a "rapidomaniac". That is all that really interests him about rivers. He rejoices in the surging water as he would in a roller coaster. Hence the amusement park designation.

At the other end of the spectrum is the wilderness river. Here the user's objective is to be alone with his group of friends in a beautiful natural setting. They run rapids, but only as part of a total experience that very much includes wilderness camping. In retrospect the white water may not even be the most memorable part of the river journey. For management, maintaining a wilderness means limiting the number of users to a level far below what the amusement park rivers can accept. And here, as we shall see, is one of management's biggest headaches.

In thinking about this spectrum (there are obviously many possibilities between the antipodes discussed) the cardinal rule for the future is the preservation of diversity. There should be amusement park rivers *and* there should be wilderness rivers. There should be rivers where jet boaters can scream upstream and rivers where canoeists can glide quietly down. Preservation of diversity is the hallmark of the American democratic tradition. It has usually been defined in *human* terms, but the concept could be extended to the *environment*. The optimum environment is diverse just as the optimum society is. The beauty of the Wild and Scenic Rivers Act is that it accomodates diversity in the amount of development. Recreational river management in the future will be challenged with the task of keeping options open for Americans, matching a particular environment to its optimum use, with an eye, always, on the relative amount of public demand for a given experience. This is why coordinated regional and national planning is essential in the future of river recreation. It may be that the Youghiogheny should become an amusement park and Pine Creek a low-use, wilderness river; the Middle Fork of the Salmon and amusement park and the Selway a wilderness.

There are temporal as well as spacial roads to diversity. In the future it may be possible--indeed necessary--to use a single river for more than one kind of recreational experience. Temporal segregation of various uses could occur. For example, May could kayak month in the Grand Canyon. In June small, rowed rafts could be permitted in numbers so limited as to protect the wilderness quality of the place. August might be big-boat and big-numbers month with volleyball courts erected in advance at the campsites. September could find small, nonmotorized boats back on the river in limited numbers. Under this arrangement a very diverse use could be made of a single river and user conflicts kept to a minimum. It is an option, I believe, that the recreational demands of the future will make increasingly attractive.

In thinking about recreational river management, as well as about the care of terrestrial areas such as those in the National Wilderness Preservation System, "carrying capacity" have been magic words. When the term was first taken from the grazing industry and applied to recreation in the 1960s, it had the appeal of a panacea. Management was simple: find out the physical, biological, and what I have called the "social" carrying capacity (Nash 1973) of an area and use a quota and permit system to limit the number of users. Problem solved, right? Wrong! No sooner were quotas established on popular areas than the question arose as to who would fill them. How, in other words, would *allocation* under carrying capacity management be handled?

The question is complicated by the fact that the recreational river user is not a monolithic group. The deepest cleavage runs between commercial (or guided) and noncommercial (private) river parties. Expressed another way, it is between Americans who want to experience a river trip but lack the equipment and expertise to do so on their own and Americans who can do it for themselves. There are, of course, other categories of river runners, such as educational groups, but the dynamite issue in the future of recreational river management will be dividing the pie between the commercial and noncommercial sectors. The issue is already the subject of lawsuit and, given the inevitability of increasing demand in both sectors and a fixed user quota, the pressures will only increase.

In thinking about this issue it is well to dispose of some confusing myths. *None* of the following are true as generalizations upon which policy should be based: (Myth 1) All commercial boatmen are demi-gods who satisfy every customer and always protect the resource; (Myth 2) noncommercial river users are pot-smoking hippies with long hair and poor equipment; (Myth 3) Only the big, expensive, motor-powered pontoon rigs can make trips on white water, like the Grand Canyon's, safely; and (Myth 4) River running is so difficult that only 22-year-old weight-lifters who have been down the particular river 20 times are competent to run a successful trip. The point of all this is that good river trips can be run by both commercial and noncommercial parties and so can bad river trips. Another point is th any reasonably well-coordinated individua can learn to row a boat on a white water river with a few days' practice. The spo is for most people less difficult to deve competence in than is downhill skiing. C mercial boatmen and outfitters frequently profess dismay at the numbers of private floaters in the country these days. In fact the commercial operation has been a major factor in creating the noncommercia interest. People who run commercially o year, and who are participation rather th service oriented, may well be running non commercially with a group of their frien the next year. The availability of good, reasonably priced equipment (see Verne Huser's paper in this symposium) facilitates their plans. I believe, then, tha there is a definite numerical relation between the numbers who run rivers commercially and the numbers who want to ru them privately.

The public is served by both commercial and noncommercail river trips. In allocating available river time between these sectors it may be helpful to consi the concept of "percentage of disappointment". The essential idea here is a management policy that aims at denying perm to the same percentage of applicants in commercial and noncommercial sectors. Alternately, it means granting permits to same fraction of applicants. An example an equitable arrangement under the "percentage of disappointment" plan would be the following:

Number of applicants for noncommercial trips	*Number permitted to run*	*Percenta of disap-pointme*
600	200	67%

Number of applicants for commercial trips	*Number permitted to run*	*Percenta of disap-pointme*
9,000	3,000	67%

The hooker in this system is determining the number of *bona fide* applicants for e sector. One method is relying on honest reporting from both commercial and nonco mercial sources. Another, with less loo holes, is for all applicants to go throu management which then conducts a lottery within each sector. The winning private parties get permits; the winning commer-

ally oriented individuals are referred to
e outfitter of their choice.

On amusement park rivers there appears be little reason to favor commercial ips over noncommercial or vice versa. t on rivers managed for wilderness values is relevant to note that the highest vidends from a trip may go to those with perior physical and psychological prep- ation. There is an adage that the more u put into something the more you get t. The person who plans a trip, organ- es food and equipment, prepares him or rself to row or paddle, and actually runs e river seems to be ahead on this score the person who simply writes a check d shows up. Any commercial boatman will mit, although perhaps not publicly, that ey get more from the trip than the attle" they herd down the river. Looked another way, if self-sufficiency is one the most important parts of a wilderness perience, then the management policy ich favors self-sufficiency (that is, do- t-yourself trips) would seem more appro- iate to a wilderness environment. As it ands, most commercial river passengers e hardly self-sufficient; even more than ided parties of backpackers (who at least ave to walk and carry), the river passen- er is caught in the safari syndrome. They n't row, seldom cook, and experience few f the satisfactions of really contributing o a wilderness journey. The "percentage f disappointment" formula does not have discriminating factor built into it, but anagement interested in maximizing the value of wilderness or wild river to the public might well want to consider discriminating against the safaris in favor of the do-it-yourselfers.

Another distinct possibility for the future of river and related backcountry recreation management is the "wilderness license". We currently require drivers of automobiles to demonstrate proficiency before being allowed to use the public roads. Why not require a similar show of competence from would-be wilderness users? The tests, which might have both written and field components, would be designed to insure personal safety, courteous conduct to other users, and protection of the resource. Certification could possibly depend on taking a course similar to the one the United States Coast Guard now offers to offshore power boat operators. The wilderness license, at any rate, would guard against the unqualified noncommercial user who does occasionally appear on rivers today.

The United States has a unique resource in its long backcountry rivers in relatively close proximity to major population centers. These rivers are worthy of the best our society can provide in the way of planning and management. And we can be sure of one thing. The decisions made today and tomorrow will create patterns that will solidify with time into institutions. The superb resource at stake should call forth our best management efforts.

SOME LEGAL ASPECTS OF RIVER RECREATION MANAGEMENT IN THE EAST[1]

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ABSTRACT.--The theme of this paper is the almost incredible multiplicity and the complex interrelation of overlapping governmental controls and private lawsuits affecting rivers and streams in the East. Its aim is to present a basic formula or approach to help identify, understand, and distinguish these interwoven legal control mechanisms. Its technique involves an octagonal form of analysis. To enliven the presentation, certain basic principles, cases, and authorities are incorporated into a form of fable based upon Siegfried's Rhine Journey.

FOREWORD

In order to condense and better exemplify certain basic principles of a complex, lengthy, involved subject, I have resorted to the time-honored approach of the fable. Because this paper is to be presented in Viking country, and is about rivers, what better form could the fable take than the old Norse legend that Wagner wove into Siegfried's Rhine Journey?

Obviously all the names, locations, characters, incidents, and events are entirely fictitious, and no resemblance to any actual persons or entities, corporate or otherwise, living or dead, is intended. Hopefully, the legal principles and conclusions set forth do have some validity and application to the real world because this is the object of the exercise.

The cases and other authorities, where cited, are actual reported cases and existing authorities, but expansions upon them, or their use in the fable are not intended to in any way reflect upon the actual participants. For example, Captain Soma Boat Line, Inc., in a reported decision in 1973, did sue the City of Wisconsin Dells for an allegedly low bridge. However, this is where it stopped. The name of the character "Commodore Coma" in the fable was deliberately chosen because not many people bear that unlikely name, and, to the best of the author's knowledge, Captain Soma Boat Line, Inc., has never been involved in any serious accident, nor is it associated with any conglomerate, fictional or otherwise, such as "Nippon-Hewes, Ltd." To any fine families of German extraction living in fictitious counties in Northern Wisconsin who might be named "Fafner," please be assured that the character "Fafner" is based on that of the 5,000-year-old talking dragon slain by Siegfried. But, to any *actual* 5,000-year-old talking dragons who might take offense, the author boldly says: *Hab acht, Brueller!*--the sword, Notung, is sharpened and ready!

A river is more than an amenity, it is a treasure.--JUSTICE HOLMES, *New Jersey v. New York*, 283 U.S. 336, 342 (1931)

Hast du dem Rhein das Gold zum Ringe geraubt?--R. WAGNER, *Siegfried*, Act II, Sc. 3

If the use and enjoyment of a river is a treasure, no gold hoard of the Nibelungs was ever jealously guarded by more dragons than today's typical back-country stretch

[1]*All footnotes appear at end of paper.*

ater. These guardians are paper ons, but fierce and numerous: laws and nances, regulations, licenses, cita-s, injunctions, trespass and damage s...this guard roster, reflecting ral, State, and local governmental rol efforts, and often including ate lawsuits, could be extended almost finitely. What is at stake? Enjoyment he treasure is directly related to the ure of legal control achieved. Effec- management requires at least a sub-tial amount of effective legal control.

The *THEME* of this paper is the almost edible multiplicity and the complex rrelation of overlapping governmental rols and private lawsuits affecting rs and streams in the East. Its *AIM* is resent a basic formula or approach to identify, understand, and distinguish e interwoven legal control mechanisms. *TECHNIQUE* involves an octagonal form of ysis.

. DISTINGUISHING PUBLIC RIGHTS AND RIAN RIGHTS

Riparian rights as they concern this y are those rights to use and enjoy a r or stream that the law confers upon owner of the land abutting the water as djunct to his ownership of the enclosing s or upland. Such rights may only be rted by that owner or someone claiming is name.

Public rights is a term lawyers and ges have traditionally used to describe tain privileged uses or enjoyments by bers of the general public in a river or eam that in many eastern States must be vigable in fact" by State law definition. concept is a peculiar one, traceable far k into the mists of the early Common Law, the rationales supporting it vary stically from State to State, and ision to decision.

Under any of the widely varying ionales used by the Courts to support it, effect of the public rights concept is accord nonriparians a share in the use enjoyment of a river or stream that erwise might be largely monopolized by vate owners along its banks. Again, the ure and extent of the uses permitted, the criteria, as to which rivers or eams fall within the concept varies kedly from State to State.[2]

There is a strong hint of conflicting social philosophies running through this court-created dichotomy--rugged individualism vs. egalitarianism, private property vs. collectivism. Serious social conflict is probably more apparent than real.[3] There are probably more conflicts today among nonriparians in asserting apparently incompatible public rights than there are between riparians as a group versus nonriparians as a group. After all, a riparian on the Brule is a nonriparian when he fishes on the Popple.

Waite (1967), in a exhaustive comparative analysis of public rights in water in four eastern States, criticizes the use of this dichotomy as being more productive of discord, emotionalism, and fuzzy thinking than of productive logical results. Nevertheless, he feels compelled to use it, stating: "In spite of the fallacies and detrimental effects inherent in placing permitted water uses in two groups labeled either "public" or "private", the distinction is still made in the cases, and lawyers customarily speak of the permitted uses as "rights." Therefore this essay, oriented as it is toward lawyers' law, continues the familiar terminology."[4] On the same basis, this paper will employ the dichotomy as a form of legal shorthand.

II. AN OCTAGONAL RELATION

The basic legal controls that surround and constrain the establishment or exercise of these rights can be illustrated by an octagon (fig. 1). The nonriparian and riparian rights enclosed by the octagon are separated by the shifting, wavy, broken line. They appear on the diagram to be fairly equally divided as to area occupied. This may or may not accurately reflect the state of the law today.[5] The important point is that the line shifts back and forth within a finite, restricted area in reaction to legislative, administrative, or court decisions. A mass of such decisions favoring exclusive use by riparians *should* crowd the public users narrowly against the sides. Likewise a mass of such decisions favoring the public users *should* limit the private rights of riparians. The diagram *should* reflect reality in that the total usable water resource is also finite and restricted. But does it? The analysis below explores this question.

To enliven the presentation, let us follow the adventures of Siegfried ("Sig")

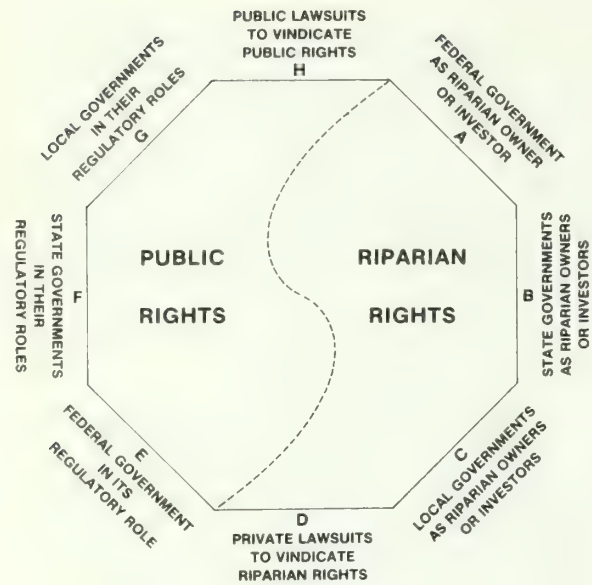

Figure 1.--*Eight segments representing the basic function of Federal, State, or local governmental management, or a lawsuit by a private interest in the courts to vindicate some respect of claimed public or riparian rights.*

Schmoe, Average American Boater, as he travels down the Rind, a river of modest size located in an entirely imaginary county of northern Wisconsin. The lettered paragraphs (A-H) below match those in figure 1.

A. THE FEDERAL GOVERNMENT AS RIPARIAN OWNER OR INVESTOR

Sig must first gain access to the river for his boat across *some* intervening riparian owner's property before he can enjoy his public right to do a little fishing. He has heard that some of the riparian owners, particularly Fafner and Alberich further downstream, are pretty touchy about trespass--particularly with boat trailers. He doesn't want to go to court or pay a fine for land trespass.

Fortunately, there are about 1 1/2 million acres of National Forest land in Wisconsin, one imaginary tract of which includes a segment of our imaginary Rind. As owner of the banks or upland, the United States is thus a riparian owner, and Sig, as a member of the public, is welcome as a licensee as long as he obeys the general regulations.[6] In the three-State Northwoods Lake Country there are about 7 million acres of National Forest land, substantial port of which are strategically located to pro access to rivers.[7]

Other Federal land-managing agencies including the National Park Service, Bure of Sport Fisheries and Wildlife, Corps of Engineers, and TVA also offer "sponsorshi to the public to get on the rivers in the East to enjoy State-created public rights

In Sig's case, by driving a little farther he finds not only legal access to river through a National Forest tract, bu also a parking area for his car and boat trailer. He parks happily noting that th other 549 or so Americans with whom he mu share this particular parking space are elsewhere today.[9]

Through additions to State and Feder properties purchases under the Federal La and Water Conservation Act, Federal grant and loans to State and local governments private groups, together with technical assistance and planning aid coordinated through Interior's Bureau of Outdoor Recr tion, the United States fills the role as "big investor" as well as "big riparian" people like Sig. According to one recent count, 90 separate Federal agencies and bureaus were contributing toward this and similar outdoor recreation efforts.[10]

As Sig prepares to launch his boat, overhears a dispute involving a Forest Service special use permittee who maintai a commercial boat livery at the launching site. A Township law officer is stoutly maintaining that carrying on a business this location is violating a Township zon ordinance, but the Forest Service Assista Ranger responds vigorously that Federal property is not subject to local zoning ordinances.[11] The noise of Sig's motor prevents his hearing the immediate outcom of this dramatic confrontation.

B. STATE GOVERNMENTS AS RIPARIAN OWNERS INVESTORS

As Sig ventures forth into the curr and leaves National Forest boundaries bel he begins to feel uneasy about whether th State courts would really find this rive "navigable in fact." He is reassured to a log floating by, and he notes several light aluminum canoes. He knows his pos is legally sound in Wisconsin, because o 1877 court ruling based on the log alone He now knows that he has a battery of wh

s have variously termed "rights" or s of the public interest"[13] including ist recreational boating, fishing, ng, and related activities. He isly must still have a valid State g license, which he has; as well as a ient six-pack. He assumes consumption latter is a sufficiently "related ty" in Wisconsin, and is about to this right[14] when his attention is d to a sight on the left bank of what ws to be State Forest land.

merging from an inlet comes Brunhilde y") water skiing behind a powerful oat. Hildy, in addition to being a beauty herself, likes to assert two well established public rights in sin--enjoying scenic beauty and water .[15]

ildy has gained access to the river State Forest land as a licensee. The of Wisconsin administers some 90,000 of State Park land, some of which has potential. Although some State tracts may be strategically located blic river access, the State has less e than some other eastern States e the bulk of tax delinquent cutover lands (totalling 1.9 million acres) rned over to County governments.[16]

Unlike the wide discretionary management ity vested in Federal land-managing es such as the Forest Service, the Bureaus managing Wisconsin's Forests rks operate under more explicit and statutory guidelines.[17]

ildy and a number of other local belles o be the centers of attraction in a s of local water ski pagents. The tee had asked the Department of al Resources (DNR) for authority to put cess ways, parking lots, and toilets, erect bleachers to accommodate the on State Forest land. The request was because the Attorney General of nsin had earlier concluded in an October decision that the DNR lacked authority nstruct spectator sports facilities in Forests, nor could it lease State Forest ty to another unit of government or to e interests for the purpose of providing tor sports faciliites such as bleachers tching a water ski show.[18]

owever, public recreation is aged in State Parks and Forests, and vision of Highways will build and maintain roads in these areas on DNR request. The DNR also has expressed statutory authority to: "...acquire the necessary land to build access roads to other lands under its care--those which otherwise would be inaccessible or which the department concludes would be increased in value and usefulness if the road were built. If other lands contain watercourses, this authority may be used to obtain access to them."[19]

State government, besides its ownership-access role, plays a pivotal role in investing State and Federal recreational funds, supervising the use of these funds through formulating and enforcing guidelines for Local government and private interests, and generally coordinating the State's recreational effort. The ORAP, and ORAP-200 programs, in Wisconsin are prime examples.[20]

C. LOCAL GOVERNMENTS AS RIPARIAN OWNERS OR INVESTORS

As Sig continues his journey, he observes Commodore Coma's excursion boat just drawing away from the shore of a County Forest tract ahead. The Commodore gained access to the river as a riparian because he owns a boat dock some miles downstream. On the river, however, he is asserting a public right of commercial boating.[21] His engine became balky on this run, but he had hesitated to put in for repairs on Alberich's or Fafner's land. He had waited until he got to County Forest land because the law in Wisconsin as to whether he would have been a trespasser on private riparian banks has been very much in doubt since *Doemel v. Jantz* in 1923.[22] This case held that the riparian owner had the *exclusive* right of access even over the strip of land between *his* ordinary high- and low-water marks. Although the courts in Missouri took exactly the opposite view in a classic 1954 test case,[23] the *Doemel v. Jantz* principle has never been flatly reversed in Wisconsin.

Governmental riparian ownerships thus offer needed initial legal access for non-riparians. They also furnish a haven for all river users in emergency situations or as pleasant stopovers for a picnic or rest.

Counties and municipalities (cities, towns, townships, and villages, e.g.) also manage forests or parks with key river *access* possibilities. For example, an extensive county park network and 1,460,000 acres of county forests are open to the public under local government regulations in Wisconsin.[24]

These local governments are "creatures of the States" in that their powers are only such as are delegated to them by the State. Nevertheless, as governmental bodies they have privileges not accorded a private riparian owner. For example, in Wisconsin: "County boards have condemnation powers to provide public highways to navigable waters. In the same manner, town boards have condemnation powers to reserve river fronts and lake shores for public use. The town also has authority to build an access road to the public shoreline area and may condemn land for that purpose. Village boards have similar condemnation powers. City governing bodies may acquire, by condemnation or other means, rights of access to and the use of waters, scenic or other easements, or other property or interests in property for public purposes."[25]

State aid for the acquisition by local government bodies of lands or interests to provide access to navigable lakes and streams is provided by various statutes including those implementing the ORAP programs. This kind of grant assistance, in expanding direct governmental property control, reflects the role of both Federal and State governments as investors as well as riparian owners.

D. PRIVATE LAWSUITS TO VINDICATE RIPARIAN RIGHTS

Ominous woods lie ahead of Sig on both sides of the river, the trees festooned with "No Trespassing" signs. He approaches the land of the grim Fafner.

Fafner is grimmer than usual. The constant roar of Hildy's towboat has put his nerves on edge.[26] He recently had to sue some nonriparians for trapping *his* muskrats.[27] Last winter some members of Hildy's Committee for an Ice Pageant celebrating "Miss Nonriparian Ice Skater" tried to saw ice blocks from *his* segment of the river.[28] He sued of course.

Now a hapless nonriparian, who has tried to bring a boat across Fafner's land, is trapped. The two struggle on the riverbank as Fafner tries to qet a license number while invoking *Doemel v. Jantz* in a terrifying growl.

If the Wisconsin Supreme Court declines to reverse or distinguish this old decision, the nonriparian will be found in trespass unless his attorney can find some suitable legal defense such as Wisconsin Statutes § 236.16(3). If Fafner had recently subdivided his land for sale, he might be subject to the following: "Where subdivisions of land are created which abut stream or lake, "public access at least 6[0] feet wide" must be provided so that publi[c] access exists at not more than one-half [mile] intervals. But the definition of subdivision is quite restrictive, and in the northern sectors of the state, *the statut[e is] often avoided or ignored.* Also, the stat[ute] has no effect on shoreland not "subdivide[d"]; for example, it is not subdivided when f[our] or fewer lots are created or when more th[an] four lots of over an acre and a half eac[h] are created. (Citations omitted, emphas[is] added)."[29]

Besides defensive suits by riparian[s] against public users, the body of cases includes riparian vs. riparian to resolve conflicting property uses, riparian vs. Federal, State, or Local Governments to resist eminent domain (condemnation); or resist regulations or zoning.[30]

E. FEDERAL GOVERNMENT IN ITS REGULATORY ROLE

The river widens. Commodore Coma's excursion boat approaches a low bridge maintained by a township. As Sig watche[s in] horror, a tall lady standing up in the b[ow] eating a sandwich suddenly drops to the [deck] as the Commodore swerves the boat violen[tly] toward the higher bridge center. Had sh[e] not dropped, she might well have had nowh[ere] to insert the rest of her sandwich.[31]

With a volley of seven-seas oaths, [the] Commodore swears to go to court to compe[l] the township to abate the bridge as a nuisance.

In his violent swerve, the Commodor[e] lost control, placing the boat in the opposite channel, so that the powerful s[tern-wheel] boat, towing Hildy rapidly back upstream, collided violently with the excursion bo[at]. In the fire and explosion that followed, [a] passenger was drowned, several others we[re] injured, and both boats were demolished. Damage claims totalling several million dollars were subsequently filed.

In several of the lawsuits filed in State courts, attorneys for both the Com[mo]dore's Company and the owner of Hildy's [tow]boat moved that the cases be removed to Federal court on the grounds that the to[w]

p had failed to secure approval for the ridge construction from the Corps of ngineers. Further, they claimed that the dmiralty jurisdiction of the Federal overnment attached under Art. III sec. 2 of he Constitution. Because the Commodore's oat and company were both owned by a large onglomerate, Nippon-Hewes, Ltd., the ractical effect might be to limit recovery f damages so as not to exceed the value of he boat under the peculiar Limitation of iability Doctrine in Admiralty Law.[32]

The township argued that although the d at the accident point was "navigable n fact" under *State* law for the purposes of he Trust Doctrine[33] and the attachment of ublic rights, it was not for the purposes of he Commerce Clause of the U.S. Constitution nd the "paramount navigation easement" of he United States. They introduced a Code f Federal Regulations volume[34] listing the ind for dredging and other national avigation improvement purposes as being avigable to the Schmidlap Memorial Bridge"- which was 3 miles downstream from the ccident site. They introduced evidence of N approval of the bridge construction.[35] o the contention that the river included aters subject to the jurisdiction of the nited States under the Coast Guard regulations because the headwaters and substantial segments flowed through National Forest land, he township introduced a letter from the oast Guard District Commandant in 1958 to he Wisconsin Legislative Council. For the urposes of enforcement of federal navigation, vessel inspection, and boating laws, he Coast Guard has interpreted the term as eaning "the navigable waters of the United tates."[36]

These are two vivid, if perhaps ypical, instances where Federal regulatory owers were *not* applied using the liberal ederal tests for navigability under the ommerce Clause. More often under this lause, such regulatory agencies as the nvironmental Protection Agency, Corps of ngineers, Federal Power Commission, ommerce Department, and Coast Guard take *ffirmative* actions such as improving or egulating navigation or building dams, *egative* actions such as prohibiting waste ischarge or regulating point and nonpoint ource pollution, or *permissive* actions such s licensing a wide variety of projects or ractices.[37]

F. STATE GOVERNMENTS IN THEIR REGULATORY ROLE

Although shaken by the tragic accident, Sig continues his Rind journey. Ahead, on both banks, lie the extensive riparian holdings of Alberich, a wealthy retired eccentric. Sig has to change course to avoid a pier jutting into the river that moors Alberich's powerful speedboat, "Wotan III".[38]

Although the Rind here "is navigable in fact" under the liberal Wisconsin test for attachment of public rights, it is upstream from the Schmidlap Memorial Bridge. Therefore, although a potential Federal "paramount" navigation easement exists, it has not yet been asserted to displace or supplement State licensing authority for the pier.

Under Wisconsin law, Alberich owns his land from each bank to the thread of the stream. Because he owns both banks, he has legal title to the entire riverbed.[39] His ownership is subject to all public rights as developed by Wisconsin case law and the legislature however. This is theoretically so because, long ago, the courts frowned on naked assertions of the State's Police Power under the Tenth Amendment. Therefore, a quasi-property concept, the Trust Doctrine, was developed to rationalize the State's "police" restrictions on the use of private property.[40] The State, and before it the Territory, were always supposed to hold the moving water body as the corpus of a trust for all the people.[41] Although the soil title passed to the riparian, the moving water did not. Therefore, the State could regulate water surface use and compel reasonable water consumption. Because Alberich's pier extends into the corpus and interferes with at least some public rights of navigation or recreation, it has to be licensed by the DNR.

The concept creates some odd results at times when literally applied, but it seems to work, and is deeply embedded in Wisconsin property law.[42]

Utilizing Police Powers under the Tenth Amendment and the Trust Doctrine, numerous bureaus and commissions centering around the DNR perform many of the same basic regulatory duties as their Federal counterparts in the *affirmative* improvement work, *negative* protective activities, and *permissive* licensing. In addition they have the added

task of supervising and approving standards for local governments when these zone or regulate river activity.

G. LOCAL GOVERNMENTS IN THEIR REGULATORY ROLE

Passing gingerly by Alberich's pier, yielding careful right-of-way to departing boats as required by local ordinances, Sig hears a violent discussion between the Chief of the township Water Safety Patrol and Alberich. A Joint Township Ordinance[43] has been adopted flatly limiting boat horsepower on this part of the river, and the Wotan III far exceeds the limit. Alberich tells the Chief that the ordinance violates Wisconsin Statute § 30.77 and is contrary to the case law. "Section 30.77 provides that any municipality may enact ordinances that are in strict conformity with the Statewide provisions regarding boating, water skiing and skin diving and with the rules of the Department of Natural Resources. Any town, village or city, in the interest of public health or safety, may enact ordinances relative to the equipment, use or operation of boats, water skiing and skin diving if they are not contrary to or inconsistent with the Statewide provisions."[44]

Because counties and municipalities are "creatures of the State", care must be exercised to avoid unlawful delegation of the State's public trust responsibilities for navigable waters. Local governments, through zoning and regulation under State superivision, may limit commercial and industrial activities and farming, define and zone flood plains, and otherwise aid the State in its role as trustee.[45]

H. PRIVATE LAWSUITS TO VINDICATE PUBLIC RIGHTS

Alberich is further annoyed because Moe Mime, the well known metallurgist and champion of public rights, has just filed suit against him alleging that because a part of Alberich's river frontage is under the Forest Cropland law,[46] he (Mime) cannot only hunt and fish there, but also bring his boat across it for river access.[47] The suit is still pending.

Meanwhile, Commodore Coma, filing suit against the township to abate the bridge (a riparian suing to vindicate a public right) is told by the court that he lacks standing to sue.[48]

CONCLUSIONS

Sig comes ashore on the highway right-of-way at the Schmidlap Memorial Bridge, ending his Rind journey. He tosses the Magic Octagon back into the Rind. He has learned:

1. That three levels of government and many agencies are busy sponsoring or investing so that more members of the public can legally get on the river to enjoy public rights.

2. That having more people on the river does not necessarily mean an expansion of public rights as court defined, although seemingly it curtails or restricts the enjoyment of some exclusive private rights.

3. That more people on the river seemingly requires more regulation by more governmental agencies, thus restricting public rights as court defined.

4. That the courts' theories rationalizing these problems have an air of unreality, founded as they are on archaic property law concepts.

5. That goals or objectives to balance all these conflicting interests are left to the creative tensions and sometimes rivalries among many levels of government. Perhaps it will work out.

Meanwhile, Hildy awaits him at the bridge in her red convertible, her blonde hair only slightly singed from the accident calling: *O Siegfried! Dein war ich von je!*[49] We'd better let him go now.

FOOTNOTES

[1]*The statements or views expressed herein are exclusively those of the author and do not necessarily represent the views or policies of the United States Department of Agriculture, nor any service, function, or agency included within or connected with that, or any other federal body.*

[2]*G. G. Waite,* A Four State Comparative Analysis of Public Rights in Water *(1967) (hereafter cited as* Waite, Comparative Analysis); *T. Lauer,* The Common Law Background of the Riparian Doctrine, *28 Mo. L.*

60 (1963); H. Ellis, J. H. Beuscher, ward, J. P. DeBraal, **Water Use Law and istration in Wisconsin** (1970) (here- cited as **Water Use Law**), especially and 9.

[3]J. A. Kusler, **Carrying Capacity ols for Water Recreation Uses**, 1973 of Wis. L. Rev. 1; G. G. Waite, **The ma of Water Recreation and a Suggested ion**, 1958 Univ. of Wis. L. Rev. 542. blistering attack on governmental ol of natural resources under Vermont 50 see J. McClaughery, **The New Feudal-**, 5 Environmental Law 675-702 (1974-): "The central thrust of the Vermont ience: the effort to replace freehold rty by social property, which is the tenet of the New Feudalism;" but e **Waite, Comparative Analysis, supra**, "Extending some control to non- ians represents a major triumph of ical democracy over land-based lism" (obviously the gentlemen differ at on their definitions of "feuda-); and J. L. Sax, **Takings Private ty and Public Rights**, 81 Yale Law l 149 (1971): "The public has rights l as property owners;" (the present 's experiences with landowner reaction Missouri Ozarks to condemnation dings for the Eleven Point River under ld and Scenic Rivers Act have convinc- that there is a problem, but the tors are still far from taking to the ades).

Waite, Comparative Analysis, supra,

The balance, in Wisconsin, seems to ung heavily in the seventies toward users rights in zoning of shoreline and regulation of riparian owners. **. Marinette County**, 56 Wis. 2d 7, 201 761 (1972). For a thorough analysis s case and the general state of the ee: F. Bosselman, D. Callies, J. **The Taking Issue** (1973), pp. 161, 217, 95.

36 CFR 251.1(a)(2) "Temporary use or ncy of National Forest lands by indiv- for camping, picnicking, hiking, g, hunting, riding, boating, parking icles and similar purposes may be d without a permit...."

Committee on Interior & Insular s, U.S. Senate, **The Recreation tive**, 93d Cong. 2d Sess. (1974), pp. 94, 177, 192 (hereafter "The Recreation Imperative").

[8]**The Recreation Imperative, supra**, Ch. 3, pp. 25-37, 84-85.

[9]**Ibid**, p. 135. In the Northeast, he would have to share with about 1,139 other people.

[10]**Ibid**, pp. 154-155.

[11]Of the 765 million acres of land and inland water surface held by the United States, 728 million acres are held in a proprietarial capacity. Less than 1/20 is held under exclusive legislative jurisdiction where the State in which the land is located has ceded all power to make laws and regulations to the Federal Government. However, under the Supremacy Clause of the Constitution and Art. IV, Sec. 3, the Property Clause, State authority to control Federal property and activities is limited: A State has civil and criminal jurisdiction over lands within its limit belonging to the United States, but this jurisdiction does not extend to any matter that is not consistent with the full power of the United States to **protect** its land, to **control** their use, and to **prescribe** in what manner others may acquire rights in them. Opinion of the Solicitor, U.S. Dept. of Agriculture, No. 728. But see: K. S. Landstrom, **State and Local Governmental Regulation of Private Land Using Activities on Federal Lands**, 7 Natural Resources Lawyer 77 (1974): Several forms of local government may overlap upon the territory within which the tract of Federal proprietary land is located. Under a complex of overlapping existing and potential Federal, State and local land use regulatory controls, and with a maze of regulatory controls from various levels of government not based on land usage, the importance of seeing that State or local governmental controls are extended to cover Federal proprietary lands may be overlooked. However, the Supreme Court, in several very recent decisions, has reemphasized that the States may **not** regulate federal installations **and activities** without "a clear congressional mandate," or "specific congressional action" that makes this authorization of State regulation "clear and unambiguous." Such Congressional waivers are virtually non-existent at this time. See **EPA v. California**, 74-1435, decided June 7, 1976, 44 LE 4781, 8 ERC 2089; **Hancock v. Train**,--U.S.--, 96 Sup. Ct. 2006, 2013; **Kleppe v. New Mexico**,

--U.S.--, 96 Sup. Ct. 2285 (1976), 44 LW 4878 (6/17/76).

[12]Waite, Comparative Analysis, supra, *15;* Olson v. Merrill, *42 Wis. 203 (1877),* Willow River Club v. Wade, *100 Wis. 86, 76 N.W. 273 (1898);* Water Use Law, supra, *40.*

[13]Waite, Comparative Analysis, supra *9 and footnote 12. The term is that of Dean Trelease who argued that the right of an individual to sue to enforce the public rights has not been clearly settled.*

[14]*Query: Would a local ordinance or DNR Regulation barring "bottles and cans" be enforceable? Or politically feasible?*

[15]State v. Public Serv. Comm., *275 Wis. 112, 118, 81 N.W.2d 71 (1957);* Muench v. Public Serv. Comm., *261 Wis. 492, 506-508, 53 N.W.2d 514, 520-521 (1952);* Nekoosa-Edwards Paper Co. v Railroad Comm., *201 Wis. 40, 47, 228 N.W. 144, 147, 229 N.W. 631 (1930).* Water Use Law, supra, *Ch. 9. Public rights in Wisconsin appear to include fishing, hunting, boating for pleasure, sailing, swimming, skating, water skiing and the enjoyment of scenic beauty on navigable waters. Many other eastern States have a much shorter, more limited list as to rivers and streams. An interesting and unresolved Constitutional question is whether the State can ever be called on to pay just compensation if it broadly expands these public rights to strikingly diminish traditional riparian rights. See* Water Use Law, supra, *pp. 42 note 100 and 68 note 198.*

[16]Water Use Law, supra, *pp. 175-176;* The Recreation Imperative, supra, *175.*

[17]*Wis. Sta. Annot § 27.05-28.11(3).*

[18]*Op. Atty. Gen., October 17, 1974 (see Wis. Stat. 28.04).*

[19]Water Use Law, supra, *176.*

[20]Ibid, *177, Ch. 353 Wis. Stat. Annot.*

[21]*See note 15,* supra. *It is sometimes difficult to determine when a riparian may be suing for diminution of value to his property or business (riparian) and when he is asserting his public rights as a citizen. See* Waite, Comparative Analysis, *p. 29, and note 17 (denial of a* monopoly *of access to navigable waters).*

[22]Doemel v. Jantz, *180 Wis. 225, 193 N.W. 393 (1923). Based on the author's research to September 7, 1976, 15 subsequen cases in Wisconsin had cited the* Doemel *ca with approval, and it had not been overrul Six other eastern States had also cited it as authority. Consider, however, the same Court's views when another factor is inser ed. In* Polebitzke v. John Week Lumber Co., *163 Wis. 322, 158 N.W. 62 (1916), it was held lawful to enter on the riparian shore for logging purposes between the two water marks. Recall the log test for navigabili and Wisconsin's past interest in the timbe industry--important insight can thereby be gained as to how the list of public rights is formed. A lot depends on the era.*

[23]Elder v. Delcour *(Missouri), 269 S.W. 2d, 17 (1954).*

[24]Water Use Law, supra, *p. 175-179.*

[25]Ibid, *176.*

[26]*Fafner has scant legal remedy at present except the law of nuisance, or possibly local ordinance violation. See: Noise Control Act of 1972, 42 U.S.C.A. § 4 et seq. Thus far, Federal efforts have be directed toward large scale aircraft and highway problems, and manufacturing sources Local noise problems have been left to Sta or local regulation. Cf.: motorcycle noi See Note 44 below for one effort by local ordinances in Wisconsin to prescribe horse power limits.*

[27]Munninghoff v. Wis. Conservation Comm., *255 Wis. 252, 38 N.W.2d. 712 (1949) held that the riparian had the exclusive right to propagate muskrats.*

[28]Haase v. Kingston Co-operative Creamery Assoc., *212 Wis. 584, 250 N.W. 44 (1933) gave the riparian the exclusive rig to use of the ice, but recognized the publ right to ice skate on the frozen surface (obviously* away *from areas where the riparian is cutting the ice). Query: in clearcut factual situation involving ice fishing, who would prevail in Wisconsin? Riparian or public?*

[29]Water Use Law, supra, *pp. 174-175.*

[30]*See e.g.,* Water Use Law, supra, *agricultural irrigation 256-262, shorelan rights 36, zoning (local government) 408, obstructions to navigation 35, access 19, 35, cattle watering, reasonable use 18,*

rotection from municipal sewer pollution 98-399, etc.

[31]*Compare with similar hazards in raveling by post coach in early Victorian gland as recounted by the devilish Mr. fred Jingle in Charles Dickens* **Pickwick pers**, *p. 33, Signet Classics (1964).*

[32]*H.L. Auten,* **The Role of the U.S. Coast ard and State Agencies in the Promotion Boating Safety,** *37 Temple Law Quarterly 6, 450 (1964); L. R. Harolds,* **Limitation Liability and its Application to easure Boats,** *37 Temple Law Quarterly 3-445 (1964); G. G. Waite,* **Pleasure ating in a Federal Union,** *10 Buffalo Law urnal 427-447, 439.; J. H. Gibson,* **ability Under State and Federal Law: ating and Water Sports,** *11 Washburn Law urnal 418-439 (1971-1972).*

[33]*See infra, notes 39-42. Rivers may be navigable in fact under the Federal test as to authorize dredging, channel improve- t, FPC dam licensing, EPA pollution ulation, Coast Guard policing and igation control, etc.; (b) navigable in t under the State test so as to authorize rcise of enforceable public rights; allow te or local agencies to apply licensing restrictions on dredging, improvements, e, etc.; or (c) non-navigable. In consin, due to the liberal test, it is d to find a river in category (c). (a) (b) can and do often coincide, and the ation or national importance of the river a segment of it is the key.*

[34]*See e.g., 33 CFR Part 2 (Coast Guard); CFR Part 209 (Corps of Engineers) - iously because the Rind is a fictitious er, you will search for it in vain by e.*

[35]**Water Use Law, supra,** *p. 487, for a cussion of the State's traditional uisdiction* **until** *the Federal Government ermines to assert its Supremacy.*

[36]*G. G. Waite,* **Pleasure Boating in a eral Union,** *op. cit., p. 442. The same ch of a watercourse might be within the uisdiction of the FPC or Department of the y, yet Federal navigation rules might not ly to it. In a letter to the Wisconsin islative Council of January 14, 1958, iral E. H. Thiele, then Commander, 9th st Guard District, stated: "Certain rivers that have been improved by the Corps of Engineers have been declared by that agency to be navigable waters of the United States throughout all or part of their length." The Admiral listed a few rivers that had been held navigable but said it was impossible to list all the Federal navigable waters in the State. The Admiral said the Coast Guard recognizes its responsibility to enforce the Federal statutes on all these waters but indicated it didn't have enough men or equipment to do so. J. H. Auten,* **The Role of the Coast Guard and State Agencies in the Promotion of Boating Safety,** *op. cit., p. 450. The Coast Guard and other Federal agencies determine which waters are navigable and thus designate the extent of their jurisdiction; i.e., they promulgate rulings or issue statements of opinion with respect to the navigability of specific waters in connection with the administration of the functions or responsibilities assigned them by Congress. However, these rules or statements of opinion do not conclusively establish jurisdiction, because the juris- diction of the United States can be con- clusively determined only through judicial proceedings. In any event, federal jurisdic- tion is determined according to Federal law rather than according to the rule prevailing in the State where the waters are located. There are several practical consequences resulting from the application of Federal Admiralty jurisdiction rather than State law in a boating accident. (1) Limitation of liability might apply. (2) No jury trial. (3) Comparative negligence, as federally interpreted--especially significant in con- tributory negligence states. (4) The weird doctrine from* **The Jumna,** *149 Fed. 171 (2d. Circ. 1906) dealing with damage arising from a cause that is "inscrutable." See D. Mattioni,* **Incidents of Maritime Collision Law,** *37 Temple Law Quarterly 456 (1964).*

[37]**Water Use Law, supra,** *pp. 474-475.*

[38]**Ibid**, *p. 166 -* **Bond v. Wojahn,** *269 Wis. 325, 69 N.W.2d 258 (1955). (Riparian vs. boater for property damage to pier extending 80 feet into the river. The court did not find sufficient evidence that the pier interfeied with public rights.)*

[39]**Ibid**, *p. 44. "The rule that riparian rights exist by virtue of the ownership of the bank or shore in contact with the water, and not upon title to the soil under the water, has been uniformly followed in Wisconsin."*

[40]Waite, Comparative Analysis, supra, 3, 19, 22.

[41]Ibid, 21, 22.

[42]Ibid, 21, 22. The same result might be reached by stating that the State's police power applies to regulate riparian activities, and that members of the public are privileged (i.e., free from a charge of trespass) as to certain enumerated activities. Professor Waite's policy arguments on continuing the doctrine (p. 19) are persuasive however. Cases such as those involving muskrats and ice (notes 26 and 27) are a little hard to reconcile as he recognizes. Treatment of the corpus in situations involving taconite development, and the bulkheading and extinction of parts of the Fox River at Green Bay also take some artful juggling. See Water Use Law, supra, 72-73, 463-465 (taconite); 153-154 (bulkheading) - Town of Ashwaubenon v. Public Serv. Comm., 22 Wis. 2d. 38, 125 N.W.2d 647 (1963); 126 N.W.2d 567 (1964).

[43]Water Use Law, supra, 615 (Appendix F) shows an ordinance promulgated in the name of two towns and a village that illustrates the joint approach. It does not have a horsepower restriction.

[44]Water Use Law, supra, 406; R. W. Cutler, Chaos or Uniformity in Boating Regulations? The State as Trustee of Navigable Waters, 1965 Wis. L. Rev. 311. See p. 317. The Town Board of Burlington, (Racine County) Wisconsin, on June 11, 1963, adopted an ordinance prohibiting operation of boats having more than 50 h.p. on waterways within the Town. Leiske, a resident having a 75 h.p. boat sued. In Leiske v. Town of Burlington, Civil No. 62-001 B, Racine County Court (4/17/64), the court held (1) Under the trust doctrine as set forth in the Muench case, the subject matter of the ordinance was of Statewide concern. (2) The 1959 Boating Act did not contemplate this kind of local legislation. (3) Even if delegation were proper, the classification standards were unreasonable.

[45]Water Use Law, supra, Ch. 15 (404-434).

[46]Ibid, 404-434, 74- 75; Wis. Stat § 38.11(1), (5); Wis. Stat. § 5.341.

[47]Ibid, 174-175.

[48]Commodore Coma might or might not be successful, depending upon the weight as a precedent accorded to Captain Soma Boat Line Inc., v. City of Wisconsin Dells, 53 Wis. 2d. 838, 203 N.W.2d 369 (1973), which appeared to say that an individual member of the public lacked standing to abate a public bridge.

[49]This and other odd-tag ends of German throughout are from the sound track of Deutsche Grammophon Gesellschaft's very fine recording of Richard Wagner's Siegried, Berliner Philharmoniker, Herbert von Karajan conducting. The author gratefully acknowledges the inspiration thus provided. Any sour notes in the transcription are his own.

URBAN RIVERS AS RECREATION RESOURCES

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ABSTRACT.--Cites examples of current recreational developments of urban waterways: San Antonio River Walk, Wichita River Parkway, Trent-Severn-Rideau Waterway (Ontario) and New York State Canal Recreation Development Program. Documents benefits: protection of natural amenities, revitalization of downtown, provision of leisure activity, and increases in jobs, incomes, and taxes generated through commercial enterprises related to development.

URBAN RIVERS AS RECREATION RESOURCES

Recent emphasis upon wild and scenic ivers tends to overlook an equally imporant segment of recreational resource--the rban river. While there is much merit in ograms to save the more fragile and primive river landscapes, the recreational pportunities of urban rivers seem even more bundant. Fortunately, in America today, ny urban river landscapes are experiencing renaissance of conservation and development nterest. Study of these trends shows that ecreational potential is high but each city mands special study and planning.

The great potential of urban rivers mes from their ability to serve so many llions of people. Both social and eco-mic gains are abundant whenever the rich source assets of urban river corridors e redirected from waste containers and rriers to places of beauty, repose, and great recreational utility. It is signifant that the National Park Service, cusdian of the prime natural wonders of the untry, should state that "There is no ubt that a thriving recreation industry uld be developed on most rivers of the ited States, and such development would most appropriate, not to say profitable, places where the river runs through avily populated areas" (Sudia [n.d.]).

RIBBON AND NODE TYPES

From a planning and development point of view, urban river recreation seems generally to be of two types--ribbon and node. The ribbon type treats a waterway as a parkway by providing an esthetically pleasing setting for distances along the watercourse. The node type provides a concentrated land-water interface at one location. Both are excellent demonstrations of waterway renewal in an urban setting.

The node type is well illustrated by the San Antonio River Walk (fig. 1). This four-by-six-block inner city complex is a concentrated mix of park and entertainment functions in a beautiful naturalistic setting. The park, points of interest, and business elements are intricately intertwined, forming a new amalgam. This amalgam has characteristics of each element but also is a unified whole with identity all its own.

A landscape analysis of the River Walk indicated that it could be divided into four environmentally cohesive but discrete areas (Gunn *et al.* 1972) (fig. 2). Area "A" contains landscaped walkways along the river but no shops. It offers open space and footpath linkage between the core and upper San Antonio. Area "B" is functionally

Figure 1.--*The San Antonio River Walk is an excellent demonstration of a node type of urban river recreational development.*

more of a destination area in a semi-tropical setting, flanked by a few hotels, a library and a hospital. Area "C" offers a pleasant landscape setting and features many shops, restaurants, hotels and places of entertainment. Area "D" is entirely manmade, excavated in 1968 to link the natural horsehoe bend of the river to a new civic center complex of theater, exhibition building, and arena.

Survey of both visitors and voters of San Antonio proved the River Walk to be a popular as well as a popularly-supported civic feature. The voters are extremely proud of it and express no concern over fact that over 74 percent of the visitor are from out of town. They know the Riv Walk as "a great thing". "We take all o visitors to the River." "I love it; I g as often as possible." "...appreciate j knowning it's there" (Gunn *et al.* 1972

The visitors, which reflect a very broad range of ethnic, age and income ch-acteristics, like it because of: "trees, quiet, nature; feel more at home than an where else;" "lots of good views, pleasa to walk along, peaceful, no cares, fact

Figure 2.--*The River Walk occupies a relatively small area in downtown San Antonio and consists of four landscape environmental zones.*

at there is a river." "Clean, green atsphere; helps relax--like a vacation spot the middle of town" (Gunn *et al.* 1972).

Although the River Walk has had both y and professional design inputs, it is t the result of one single plan at one ne. Perhaps this is in its favor. It s avoided a narrow, single-purpose and erile atmosphere that sometimes results om singular planning effort. Local citen groups, governmental offices, archicts, landscape architects and engineers ve made valuable input from time to time. e visitor expressed his reaction this r, "Designed in sense that keeps human oportions, not regimented; not a national k, but commercial and natural--takes o account all human activities--dining, ht life, relaxing; fact is downtown but pletely divorced from city; like in ntry" (Gunn *et al.* 1974).

Rather than wait for some single agency conceive, plan, and manage this area, many as six major organizations and ncies collaborated on River Walk planning management. It demonstrates that it be done, and done effectively, and, at same time, that the integrity of each anization is retained.

The ribbon type of recreational river development may have focal points but is dominantly a linear corridor concept. The city of Wichita is pursuing this concept along the Arkansas and Little Arkansas Rivers (fig. 3).

Stimulated by urban blight in the core of the city, plans call for redevelopment of the entire corridor, from core to the countryside, both to the north and south. "To be able to hike to the country from the heart of the city brings a great recreational resource close to those whose needs are greatest." Thus was the challenge expressed in a report in 1968 (River Corridor 1968).

Contrary to the node type of urban recreational water use, the theme is one of a series of regional parks utilizing both river and riverside. This linkage between the river proper and its setting was identified early in Wichita--a part of the comprehensive plan of 1923, park concepts in 1934, and open space and park plans in 1965 by the Sedgwick County Metropolitan Area Commission (River Corridor 1968).

Rather than provide concentrated recreational destination uses, such as those of the San Antonio River Walk, the objectives here are to provide for activities dispersed

Figure 3.--*The ribbon type of urban river park and recreational development is being implemented in Wichita, Kansas along the Arkansas River.*

throughout the river corridor. These include: walking for pleasure, driving for pleasure, bicycling, sight-seeing, boating, nature walks, horseback riding, water skiing, and hiking. Plans for the acquisition and redevelopment of sites for these purposes are gradually being implemented.

As is true for most urban river recreation development, water stabilization is critical. Wichita implemented its plan for flood control in the early 1960's, directing flood waters around the west side of the city. Through urban renewal, strong city council leadership, and other sources, an inflatable dam has created an important reservoir. This water body offers a variety of esthetic and recreational activities and ties the new convention center to hotels and other adjacent land uses. Aquatic festivals and other recreational uses now spark interest in downtown activities (Gunn *et al.* 1974).

Through strong leadership of the planning director and public support of programs to improve the water corridor throughout the city, Wichita now enjoys a major renaissance of water as a civic amenity in the everyday life of its citizens.

URBAN-RURAL SYSTEMS

Recreational waterways that include both urban and rural (not wild) settings offer a new challenge with great promise for both node and ribbon types of development. Instead of treating each segment (urban and rural) separately, there are advantages of coordinating plans. Two outstanding examples, one in Canada and one in the United States, are worthy of study.

The Trent-Severn-Rideau Waterway in Ontario (fig. 4) extends 425 miles and utilizes old water transportation routes, originally used by Indians and fur traders (Rideau 1971 , Quinte 1973). The waterway was built for commercial shipping purposes in the early 1800's to avoid Indian and American conflict in the open waters Lakes Ontario and Erie. Therefore, both land and water recreationists now have opportunities of viewing both urban and rural landscapes and historic sites along the way.

Of special interest are the 92 locks linking 33 lakes and 6 major rivers. Many of the locks are still hand operated, jus

Figure 4.--*The Trent-Severn, Bay of Quinte and Rideau Waterways are interconnected and offer a 425-mile scenic and historic corridor in Ontario, Canada.*

they were from the beginning. At erborough is the highest hydraulic lift ck in the world. Two chambers, 33 by 140 t, actually lift and lower the boater in water a height of 65 feet to the next el of the canal.

Of course, the greatest obstacle to nning such a corridor is the complexity existing development and levels of ernment. The waterway corridor has a ulation of 800,000; includes 6 cities, owns and 19 villages; and includes ions of 104 municipalities, 2 regional ernments and 9 counties. The federal ernment has control of the water and k-site lands but other public lands ain with the Crown in the right of ario. In 1969 on the Trent-Severn seg- alone, there were 25,000 cottages en e and an additional 12,000 cottages on cent reservoirs. About 26,000 vessels these waterways for recreation purposes y--there is no longer any commercial use.

As a result of growing interest in rec- ional use of these old commercial ship- lanes, the federal Minister of Transport the Ontario Minister of Tourism and In- ation announced in 1967 that both federal provincial governments would jointly y and plan for the future of this cor- r. The Canada-Ontario-Rideau-Trent- vrn (CORTS) Committee was formed and sored studies resulting in two major rts that were given wide circulation. e reports provided basic descriptive rmation about the corridor and stim- ed both private and governmental action. ebruary 20, 1975, a CORTS signing cere- n launched further action, forming two action groups to develop further work (CORTS 1975). One was the CORTS Advisory Committee composed of private citizens and the other was the CORTS Agreement Board providing government input.

Already, some development oriented to the waterway, in addition to the locks and lock sites, has taken place. The federal government has committed $44 million to the waterway over the 4 year period, 1975 to 1979. In 1973, the total cost to government was about $12.9 million. Restaurants, marinas and parks are being added. New services--lodging, tours, restaurants--are needed. The regional office of Parks Canada is inventorying characteristics of their lock sites along the Rideau. Ontario is initiating a program of provincial development policy and plan for their lands. While much is still in the planning stage, this waterway corridor represents a concerted regional effort to coordinate development for objectives of recreation and tourism as well as for conservation.

The New York State Canal Recreation Development Program represents another example of rural-urban regional waterway planning and development (New York 1975). The 524-mile Barge Canal route shown in figure 5 was chosen as the first effort of the State in establishing the Statewide system of recreationways. As with Ontario, these were originally constructed for commercial transportation. Portions still offer this but recreational use continues to outstrip this function. Included are the Erie Canal, Oswego Canal, Cayuga-Seneca Canal and the Champlain Canal.

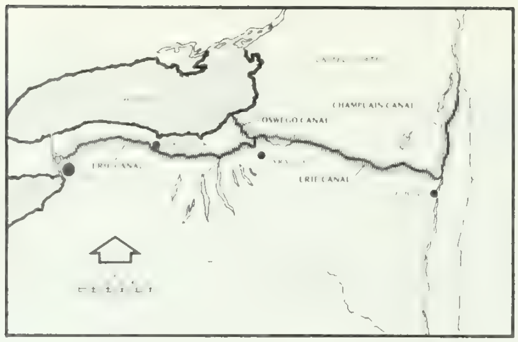

Figure 5.--*The State of New York is developing the recreational potential of a 524-mile corridor of old barge canals.*

The planning and development of this extensive corridor is both urgent and complicated. Portions of the waterway are already overused, especially urbanized areas with a notable need for boating, camping, day-use, fishing, winter and trail activities. The Canal passes through 21 counties, two-thirds of which are highly urbanized. The population of the region was 4.27 million in 1975 and is projected to be 5.05 million by 1990.

Rather than create a new canal authority, New York has decided to plan, develop and manage on a collaborative basis using existing agencies. The key actors are the State Department of Transportation (DOT) and the Office of Parks and Recreation (OPR). DOT manages the canal system and retains transportation as primary responsibility. It also operates and maintains those parks and trails located at lock sites. OPR has responsibility for recreation, agreeing that recreation shall not interfere with transportation functions. The agreement between DOT and OPR allows for policy changes as the planning process dictates and as experience, awareness and usage evolve. "This flexible attitude will allow new demands and knowledge to be incorporated into the system" (New York 1975).

In addition, many other units of government and local community groups are becoming an integral part of the program: the Department of Environmental Conservation, Bureau of Outdoor Recreation, Corps of Engineers, National Wildlife Service, National Park Service, Soil Conservation Service, regional planning boards, town, village and city planning agencies and trail and historical societies. OPR is working closely with local zoning boards and deve opers to create compatible land uses adja cent to lock sites and waterway parks. F example, "during the summer of 1973, six canal parks and three trails were develop by OPR in cooperation with DOT as a pilot project. The project was an overwhelming success with an attendance of over 200,000 in one season and became the basis for c tinuing canal development" (New York 19

Recommendations have been made for 100 sites on the entire waterway. In ea comments are made on the type of recreational activity desired, the physical development needed, and the agencies who n to collaborate for development. Most of the recommendations are for swimming, ca ing, ice skating, horseback riding, boat g, snowmobiling, motorized vehicle use, hur ing and fishing, but emphasis is also pl ed on interpretive programs and development of historic sites and structures.

In 1975, about 174,000 people used e canal parks; another 30,000 used the ol ow path trails. The State park attendants t only maintain the lock parks but also p vide interesting interpretive programs the visitors (Dyer 1976). While most this use was at the State park lock sit , additional canal facilities are being d veloped by municipalities of St. Johnsv le, Fulton, Montezuma, and Lockport (Guide Outdoor Recreation 1976).

This example is also demonstrating ew collaboration and cooperation on a larg scale to provide new recreational oppor tunities from urban and rural waters at he

same time they are given greater conservation and protective measures.

REDEVELOPMENT PROBLEMS

Because most urban rivers have been used (and abused) for other purposes, recreational use today generally demands *re*development. This is not an easy task. It is complicated by the differences between cities--physical setting, historic background, financial capability, policies, and objectives. Hanna's study in 1974 of 119 major cities in the United States revealed that even though redevelopment is plagued with many obstacles, it is taking place.

For example, out of 107 major cities that have water resources suitable for redevelopment, 68 had proposals, 59 had proposals that had reached the planning stage, 28 were implementing plans and 14 had completed some kind of waterfront development (Hanna 1974). And, most of this interest has developed since 1960. A follow-up study in 1976 shows that 12 more cities have begun implementation (Hanna 1976).

The initiators of projects were about equally divided between government and nongovernment groups. However, the majority (64 percent) of projects that have resulted in development were initiated by nongovernment organizations, such as downtown businessmen, historical societies, service clubs, Chambers of Commerce, environmental groups and professional designers and planners. Hanna found that park departments play a passive role, both for proposal initiation and implementation of projects. At the same time, if a nongovernment agent, such as an architectural group, goes too far too fast, there is evidence to suggest the plans will be aborted. Local governments, at least for urban river recreation projects, appear to function well as response agents but not as initiators.

Most cities have difficulty with funding. Many cite this as the main obstacle for redevelopment. Funding for planning comes from a variety of sources but funding for development generally comes from city and federal sources.

Some responses from cities indicate the difficulties as they see them. Galveston-Texas City--"Resources not readily available--too many restrictions in the city core." Colorado Springs--"To date, the city has turned its back to its waterways." Harrisburg, Pennsylvania--"City has not had the financial resources to expend on park and recreation expansion" (Hanna 1974).

Hanna offers the following suggestions for cities contemplating redevelopment of water resources for recreation:

1. Treat every situation as unique. Solutions in other cities may not apply.
2. Create a proposal with which the community can identify. Blue-sky proposals are bound to defeat.
3. Citizen participation in both planning and follow-through is important.
4. An opportunistic approach that links development with some major event, such as a fair, has merit.
5. Anticipate funding problems before they develop.
6. Commitment by someone with action authority is important.
7. Anticipate sources of opposition and develop research information that either corrects improbable plans or refutes the opposing arguments.
8. Enter into redevelopment with a high degree of professionalism--designs that are creative but functional; funding that is possible; social sensitivity to needs of the community; a sensible relation to local economics.

Further analysis of studies of urban recreation potential revealed the need for following a series of guidelines even though each city has unique conditions (Gunn *et al.* 1974). These guidelines included three phases:

(1) A city should perform a preliminary investigation to identify water resources and to assess their characteristics, especially the factor of water level control. There is little need in proceeding further if flooding is a threat.

(2) Based upon the outcome of the preliminary investigation, a three-part investigation in depth should take place. An appraisal of the motivating factors should be made. An analysis of the site factors will indicate the potential for urban recreational use. Other factors, such as land economics, transportation and other externalities should be investigated.

(3) If the results of the above

studies are favorable, conceptual solutions and recommendations for development and implementation can be made.

CONCLUSIONS

Review of urban river development shows many gains in recent years. Truly a renaissance of urban waterfronts is taking place.

There is growing evidence that the recreational redevelopment of urban rivers can stimulate revival of downtown vitality. This is important at a time when urban core decay is more likely the rule. Property values can be recovered, civic interest can be redirected downtown, and business can be stimulated from both local and tourist markets.

Social gains from urban river redevelopment are great. Opportunities are abundant for ethnic mixing, for pleasurable relaxation, for low cost leisure, for diversity of interests, and for the re-establishment of a civic cultural center.

The planning-through-building strategies are difficult and not uniformly applicable to all cities. Each city has its own physical, social and political conditions that will influence approaches. Generally, however, there must be strong commitment on the part of political leadership.

There appear to be two patterns of development appropriate for urban recreation redevelopment of rivers: the "ribbon" type and the "node" type. Each is suited to different recreational functions and has its own special planning problems.

Traditional categories of either parks or business blocks may not be as well suited as newer and more creative concepts. For example, the park-business amalgam, illustrated by the San Antonio River Walk, provides the advantages of parklike settings and beautiful landscapes and yet offers opportunities for cultural activity, entertainment and economic gains from certain businesses, particularly restaurants, gift shops, conference centers, and hotels.

The urban-rural context is an important foundation for planning recreational river systems. Because many separate cities and counties are involved, individual local action--both private and public--is required. However, the extensive dynamics of rivers demand high level coordination, probably best carried out at the State level.

Urban river recreation is a growing and vital segment of total water recreation development that now holds great promise for both social and economic impact, if planned and managed to do so.

PROBLEMS RESULTING FROM THE INCREASED RECREATIONAL USE OF RIVERS IN THE WEST

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ABSTRACT.--Discusses impacts and conflicts created by increasing recreation use of rivers in the western United States. Problems addressed include environmental, social, and administrative interrelationships on rivers.

Rivers are fragile ecosystems that epresent a multiplicity of resource values s well as recreational opportunities. Al- hough users of western rivers face roblems essentially similar to those in he East, certain impacts and conflicts are nique. Traditionally, resource managers ave lacked data to develop specific guide- ines for increased recreational use while t the same time keeping resource damage o an acceptable level. The challenge efore us is not only in our ability to ollect social and ecological data but to nterpret and apply this information hrough the heat of controversy, planning, nd decision making. Land managing gencies are faced with many river manage- ent problems created by increased user ressures, reductions in supply of quality hite-water rivers, and myriad environ- ental, social, and administrative problems.

SUPPLY

Rivers, whether placid, wild, or cenic, are a limited resource, and the xisting "supply" is under great pressure rom a multitude of users. At one time, ost rivers were pristine, pure, and lentiful, but the continuing encroachment man has reduced their quantity as well s their quality.

To illustrate, as of June 30, 1975, 3 storage dams and dikes and 325 storage servoirs, affecting thousands of miles of ivers in the West, had been constructed, habilitated or were under construction by the Bureau of Reclamation (Bureau of Reclamation 1975a). Although statistics on miles of rivers affected by impoundment projects is not known, channelization, dredging, landfills, and related construction of roads, trails, bridges, pipelines, wells, power stations, and transmission structures all affect the quantity and quality of the resource. A good example is the proposed New Melones Dam on the headwaters of the Stanislaus River in California, planned for completion in 1979. Currently, a 10-mile stretch of this river receives 78,000 visitor days[1] of use during a 6-month season. Most of this use would no doubt be shifted to other white-water rivers in northern California if this part of the Stanislaus is replaced by the reservoir.

Agriculture also has a real impact on rivers in the West. Water is removed for both croplands and livestock. These uses reduce the recreational quality of the river in terms of both esthetics and available water flow.

Exploration and development of energy resources has also taken its toll in reducing streamflow quantity as well as quality. Mineral extraction, desalinity

[1]*Vistor day: an aggregation of 12 visitor hours, where a visitor hour is the presence of one or more persons on land and waters for outdoor recreation purposes for periods aggregating 60 minutes.*

projects, and geothermal research place an additional drain upon the river ecosystem and surrounding recreational land. Proposed projects such as the development of phosphate resources in southeastern Idaho and the strip mining of coal in northwest Colorado are specific examples.

DEMAND

Increased leisure time and income, coupled with greater mobility of recreational marine equipment, have resulted in a phenomenal increase in recreational boating and water-related activities (fig. 1).

On the wild segment of the Rogue River, Oregon, total use increased from an estimated 2,800 visitors in 1971 to 7,200 in 197[illegible] Similarly, use on the Rio Grande River, New Mexico, increased from a total of 17,000 visitor days before 1968 to 108,000 in 1974. More people floated the Colorado River through the Grand Canyon in 1972 than did from the period 1869 to 1969 (Dekker 1976). In 1973, on the Stanislaus River, California, recreational use was estimated at 31,000 visitor days and increasing at a rate of 10 to 15 percent per year (Welton and Harlow 1973). Noncommercial and special-interest use are also on the rise. Desolation Canyon in Eastern Utah saw a 250-percent increase in use from 1973 to 1974. Westwater Canyon on the Colorado River near Moab, Utah, experienced a 380-percent increase during the same period.

Figure 1.--*The amount and variety of river use have increased tremendously in recent years.*

PROBLEMS

Certain environmental, social, and dministrative problems consistently ecur, according to river users, recreation lanners, and resource managers.

Environmental Problem

Sanitation

A constantly moving ecosystem is ifficult to analyze and protect from the mpacts of increasing use. How to maintain leanliness of portages, campsites whether designated or not), roads, trails, wimming holes, and picnic areas, as well s the water itself, is a constant concern. revention of litter equals disposal echniques in terms of complexity.

The problem of waste disposal on sites ccessible only by boat is complicated by ealth sanitation standards that prohibit nstallation of pit-toilet facilities. his causes problems on small campsites ith limited space because the next lternative--chemical toilets--requires egular servicing from some type of ehicle. An example of controversy that an be created was the Bureau of Land anagement's use of helicopters for removal f waste-holding tanks along the Rogue iver in Oregon. Economical, self-ontained portable units removed by elicopter were the selected method while isual and noise pollution trade-offs ere made.

Another controversial problem is the etermination of who should be required to ake along portable toilets on downriver rips - the lone traveler or groups of a rescribed size?

We are slowly recovering from the radition of using rivers as garbage isposals. However, it is still too ommon a sight to see junked cars, old efrigerators, and assorted debris along he river banks.

egetation

Trampling, compaction, and removal of egetation for firewood by river users, ikers, and equestrian groups can cause ortage erosion, campsite deterioration, nd a general reduction in visual attractiveness along rivers. Poor design and construction of launching sites frequently adds to the deterioration of the resource. Inadequate parking facilities, campsites located above high water marks, and spectator concentration areas all lead to additional deterioration of the vegetative cover along the rivers.

Fire

Fire is still a major protection problem along river corridors where recreation occurs. The required use of spark arresters on stoves, fire pits, fire pans, fire blankets; restrictions on the number and types of fires allowed; and restrictions on the use of fuel (driftwood, dead-down, charcoal) are all fire protection methods that generate a variety of management problems.

Social Problems

Safety

One of the major concerns of Western river managers is the protection of the visitor's health and welfare. The manager utilizes information and education systems, rules and regulations, zoning, facility design and maintenance, patrolling, sanitation standards, search and rescue programs, and enforcement programs to promote public safety.

This is complicated on rivers where the ownership changes frequently along a stream and where gaps and overlaps of management jurisdictions exist. There are now rivers in the West where a group can float through the jurisdiction of at least 3 Federal agencies.

The variety of float equipment used - inflatable rafts, kayaks, surfboards, innertubes - makes it difficult to promote user safety.

Another serious safety hazard is the variability of river conditions with different streamflow levels. Unless recreation users understand the implications of a specific streamflow level they may not be prepared for hazards that exist during these conditions. River running during high runoff periods can be fatal even for the expert. However, most agencies administering the rivers cannot

legally prohibit users from entering the river.

Additional hazards are always present such as water conditions (temperature-potential hypothermia, flow-flood hazard), use of alcohol, glass and breakable equipment, and natural obstructions such as log jams, as well as artificial obstructions such as debris. To what extent should a managing agency provide for public safety? Can you separate safety from convenience when providing guide service? These and other questions arise when talking about safety and should be addressed.

Conflicts Between Uses

Probably one of the better examples of user conflicts is found on the Lower Colorado River between California and Arizona where jet boats zoom up and down the river while people float along in the same area in innertubes. There are rivers, such as the Bruneau-Jarbridge and Owyhee in Idaho, where use is limited to non-motorized boats, but on many others, such as the Rogue in Oregon, there are no restrictions on type of craft.

A potential problem is the conflict between motorized use of a river and the inclusion of that river in a wilderness designation which would by definition prohibit motorized use.

Allocation of Use

Apportionment of use, and identification and categorization of users pose difficult challenges in both the East and West. Should use be apportioned equally among all users? What are the rights of various users (i.e., commercial, non-commercial, educational, special interest, organized, unorganized, private, public, civic, profit, or nonprofit) in receiving allocations and use permits? How should we categorize user types? Are certain user rights greater than others? What is the most effective permit system: lottery, first-come-first-serve, no-repeat, or some combination? How should allocations be balanced and distributed among users? For example, in Canyonlands National Park commercial outfitters transfer passenger day[2] allocations among themselves in order to balance use ceilings and aid other outfitters in seasons of heavy or light use. Do allocations acquire a tenure or value? In some situations commercial guides are not making full use of the amount they request. In the Desolation-Gray Canyon segment of the Green River in Utah, 10 out of 38 guides made no use of their allocations at all and 10 other guides used less than 25 percent. Should time limits be set to use or lose permit allocations?

How many, if any, qualified commercial operators are needed to effectively meet demand? Which type of use meets the public demand better, the commercial operator or the private party? What about the educational, civic, organized, scouting, and church groups? There is support for recognizing educational use as a separate category with a separate allocation of use.

Administrative Problem

Managers are confronted with myriad administrative problems in dealing with recreational use of rivers. They constantly make decisions on complex, sensitive issues without adequate resource and user data. Additional studies are needed. Reliable estimates of use exist for very few rivers (Lime 1975a). Data needs include carrying capacity (ecological, social, and perhaps economic), socio-economic, demographic, economics of commercial operations, user group ratios, user patterns and preferences, trends in use, desired experience levels, motivations of the user, and restrictions on use.

Carrying Capacity

Managers want the answers to a number of questions about a river's carrying capacity. How much use can be allowed without permanent deterioration of the resource? What level of use can be allowed without jeopardizing the type

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[2] *Passenger day is synomymous with User day: any calendar day, or portion thereof, that an individual is accompanied or serviced by an operator or permittee on the public land.*

xperience provided? How can river use e effectively monitored? For example, an crowded rivers be managed to provide "wild" experience? Do groups of users ssume an expected experience level? How ffective are the methods of distributing se, i.e., limiting launches, controlling he number of users per boat, providing onthly allotments, allowing unrestricted se in off seasons?

ermit Allocation and Fees

Permits and fees are key management ools to allow the recovery of admini- trative costs, protect resource values, nd assure the continued provision of pecific recreational experiences.

When there are more permittees than ecessary to provide adequate service to he public (e.g., provide use up to the lloted limit), some permittees opera- ions become economically marginal. Man- gement alternatives include a use-it or ose-it policy or a policy of allowing he transfer of allocations. Setting a se or lose policy for permit allocations ay or may not solve the problem. If ransfers of passenger days are allowed, echniques for adjustments are difficult. inimum allocations need to be defined o determine the bottom limit for ommercial feasibility. One of the more olatile issues involved with permits is he requirement for the permittee to have iability insurance. Getting insurance ompanies to provide coverage has been ifficult in some States.

nforcement

Trespass over and through public, rivate, and State land is a continuous roblem for managers trying to control ccess to rivers. Protection of geologic, rcheologic, and historic values is a ajor concern. Controlling vandalism, nspection of vessels and equipment, fire rotection, pollution, issuance of itations, visitor safety and rules and egulations are all elements of an nforcement program. Agencies such as BLM, lacking any immediate authority, must rely upon local sheriffs or other agencies to cite violators.

The multi-agency problem is further complicated by intermingled private, commercial, and agricultural land patterns on key river segments. Control is limited where such land is located at access points.

Interagency Coordination and Research

In many cases, recreation plans for portions of a river under different agency jurisdictions have not been fully coordinated. Chubb and Bauman (1976) found that, in many cases, National Forest plans are not coordinated with the plans for river management of State or other Federal agencies. Perhaps the overall management picture should be addressed at least at the regional level. The establishment of the Interagency White-Water Committee is a good example of the type of action that has helped in this area. Perhaps even a nationwide policy review should be considered to answer questions on proposed use allocations and variance in use policies among river segments that have the same management designation. Maybe master plans for rivers, backed by legislation, would benefit all rivers wherever their location.

Only after additional research on such topics as user demand, allocation priorities, types of use, and carrying capacities can we begin to solve some of the environmental, social, and administrative problems faced by the river manager.

CONCLUSION

This review of the problems points out some of the already identified problems. We can expect new areas of concern to arise as pressures continue to build. Solutions to these problems must be found or those rivers that remain available for recreation use will continue to deteriorate under the impacts of this use.

LEGAL ASPECTS OF RIVER RECREATION MANAGEMENT IN THE WEST

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ABSTRACT.--The paper analyzes the levels of law with which the river manager should be familiar, with emphasis on recent Federal statutes affecting the use of the Nation's waterways. It also analyzes the effects of a determination as to the navigability of a waterway, the importance of the reservation doctrine, and the effect of existing and future appropriations on river recreation management.

This paper provides a brief overview of the laws and legal doctrine applicable to river recreation management in the West, so that the river recreation manager will understand the legal framework upon which lies his authority and the authority of those with whom he must work. The legal framework includes the U.S. Constitution, interstate compacts, the various State constitutions, Federal and State statutes, county and local ordinances or laws, and case law. Of all of these, the statutes are the most significant. The constitutional law is important because it provides the basic authority for each level of government, even if in all cases, the full authority is not exercised. Case law is less important, but is helpful in illustrating points or in understanding how various laws are interpreted.

U.S. CONSTITUTION

The U.S. Constitution has four clauses of particular significance in this area: Property Clause, the Commerce Clause, the General Welfare Clause, and the Supremacy Clause.[2] Of some importance is the Tenth Amendment, which provides that all powers

[1]*The opinions expressed herein are those of the author and do not necessarily represent the opinions or views of the Department of Agriculture, Office of the General Counsel.*

[2]*The various powers as they appear in the Constitution are as follows:*

General Welfare. *Art. I, § 8, cl. 1. The Congress shall have power to...provide for the common Defence and general Welfare of the United States;*

Property Clause. *Art. IV, § 3, cl. 2. The Congress shall have Power to dispose of and make all needful Rules and Regulations respecting the Territory or other Property belonging to the United States;*

Commerce Clause. *Art. I, § 8, cl. 3. The Congress shall have power...to regulate Commerce with foreign Nations, and among the several States,...*

Supremacy Clause. *Art. VI, paragraph . This Constitution, and the laws of the United States which shall be made in Pursuance thereof; and all Treaties made, or which shall be made, under the authority of the United States, shall be the supreme Law of the Land; and the Judges in every State shall be bound thereby, any thing in the Constitution or Laws of any State to the Contrary notwithstanding.*

Tenth Amendment. *The powers not delegated to the United States by the Constitution, nor prohibited by it to the States, are reserved to the States respectively, or to the people.*

not delegated to the United States are reserved to the States and to the people. It is significant that what is commonly called the police power is not delegated to the United States.

STATE AND LOCAL LAW

As far as the State constitutions are concerned, there are three important clauses. One is the presence in various forms of the police power. This permits the State to regulate the activities of its people and the use of its land.

Second, as important as the police power itself is the extent to which it is delegated to local governments. The authority of the local units of government depends upon what is delegated to them by the States. Their functions and importance to the river manager may vary, depending upon whether it is a water district, soil conservation district, drainage district, city, or county, and the powers granted to each by the State. When exercised by a county or city, the authority appears in the form of zoning ordinances. The impact of these ordinances on the river manager can be significant and will vary depending upon whether the local authority is development- or protection-minded. In many situations, Federal, State, and local interests may be involved. The river manager should have a knowledge of the underlying legal framework in order to resolve those problems where the interests and powers are not only overlapping but conflicting.

The third provision is that which, in several States, declares that all waters in the State are public waters.[3]

[3]Wyoming Const. *Art. 8, § 1. The water of all natural streams, springs, lakes or other collections of still water, within the boundaries of the State, are herby declared to be the property of the State.*

New Mexico Const. *Art. XVI, § 2. The unappropriated water of every natural stream, perennial or torrential, within the State of New Mexico, is hereby declared to belong to the public and to be subject to appropriation for beneficial use, in accordance with the laws of the State. Priority of appropriation shall give the better right.*

Diversion Lake Club *v.* Heath, *86 S.W. 2d 441 (Tex. 1935).*

People *v.* Truckee Lumber Co., *48 P. 374 (Cal. 1897).*

Ex Parte Meier, *37 P. 402 (Cal. 1894).*

FEDERAL STATUTORY LAW

Although the constitutional framework is important, it would be unusual for a river manager to resolve a management problem solely by considering or applying the relevant constitutional principals. This is particularly so because, in many cases, the full constitutional power is not exercised. Usually, statutory law establishes the mechanism or system under which the river manager operates. At the Federal level, there are several Acts that affect river recreation.

One is the Wilderness Act of 1964, 16 U.S.C. § 1131. While not directed at rivers, it may include rivers within established units of the National Wilderness Preservation System, such as the Selway River within the Selway-Bitterroot Wilderness. The Wilderness Act provides for the management of wilderness areas in such a manner as will leave them unimpaired for future use and enjoyment as wilderness, and devotes wilderness to the public purposes of recreational, scenic, scientific, educational, conservation, and historical use (16 U.S.C. §§ 1131(a), 1133 (b)). However, the President authorizes water resource projects (16 U.S.C. § 1133(d) (4)), but this authority has not been delegated.

In the Wild and Scenic Rivers Act of 1968, 16 U.S.C. § 1271, Congress established a system composed of wild, scenic, or recreational rivers. Section 10(a) establishes the management direction for components of the system: they are to be managed to protect and enhance the values for which they were included in the system, with emphasis on esthetic, scenic, historic, archeologic, and scientific features.

Section 5(c) requires the study of proposed rivers be conducted in cooperation with the States and political subdivisions of the State, and that the study contain a determination of the degree to which the State or its political subdivisions might participate in the preservation and administration of the river. Section 10(e) provides for cooperative agreements and participation by the States and their political subdivisions in the planning and administration of components of the system that include or adjoin State or county-owned lands.

Section 7(a)(b) prohibits the FPC from licensing, and any other Federal agency from

assisting in, a water resources project that would directly and adversely affect the values for which the component was designated. The authorization of water resource developments outside the component that do not diminish the scenic, recreational, or fish and wildlife values is not affected.

Section 13 is of particular importance because of what it states the Act does *not* do:

(1) It does not affect, with certain exceptions, the jursidiction or responsibilities of the States concerning fish and wildlife.

(2) The jursidiction over the waters of a stream shall be determined according to established principles of law.

(3) It does not constitute a claim or denial by the United States to exemption from State water laws (a similar provision is in the Wilderness Act).

(4) Designation of a stream is not to be construed as a reservation of the waters of that stream for purposes *other than those specified* in the Act, or in quantities greater than necessary to accomplish those purposes.

(5) It does not affect the existing rights of any State to the bed of navigable streams, tributaries, or rivers.

(6) Nothing in the Act may be construed to alter or conflict with the provisions of an interstate compact.

Some other Federal legislation includes the legislation establishing the national forest, park, and wildlife refuge systems, and the public lands managed by the Bureau of Land Management. While directed primarily at Federal land, the definition of both National Park System and National Forest System includes the term "waters." Also, there is one case upholding the authority of the Park Service to regulate activities on waters within the boundaries of a National Park.[4] This decision was based, in part, on the definition of National Park System. In addition, the Park Service has sought legislation (H.R. 11887) that would provide a clear basis in the commerce clause for such regulation. Both the Corps of Engineers U.S.C. § 1) and the Coast Guard (14 U.S.C § 2) have authority to regulate the use o navigable waters. While this has been pr marily exercised where there is commercia boating and a definite need for uniform rules of navigation, the authority extend to all navigable waters. Of related importance are the various authorities possessed by the Federal Power Commission, the Nuclear Regulatory Commission, the Corps of Engineers, the Bureau of Reclamation, and the Soil Conservation Service. These agencies have the authority to license, sponsor, or undertake water resour projects that could convert a free-flowin stream into a reservoir, concrete channel or cooling tank.

However, as indicated, both the Wilde ness Act and the Wild and Scenic Rivers Ac contain provisions restricting water resou projects. Two other Acts of some interest are the Federal Water Pollution Control Ac particularly the 1972 amendments, 33 U.S.C § 1251, and the Endangered Species Act of 1973, 16 U.S.C. § 1531. The former is important because it requires a permit befor any discharge from a point source and because of the potential requirements of compliance with best management practices before proceeding with any activity that mig result in the runoff of pollutants from a nonpoint source. In addition, EPA is requiring, as a condition for approval of an State plan, an antidegradation policy to preserve waters that are of higher quality than current State standards. Finally, th FWPCA presently provides a significant degree of protection to wetlands under secti 404.

The Endangered Species Act provides protection for listed endangered or threatened species of plants or animals. The Act has already been involved in two water cas the pupfish in *Cappaert* v. *United States* (U.S.L.W. 4756, June 7, 1976) and the snail darter in *Hill* v. *TVA* (Tenn., May 25, 197) The Historical and Archeological Data Act, Pub. L. 93-291, 16 U.S.C. § 469, the Natio Historic Preservation Act, 16 U.S.C. § 47, and the recent Act (S. 327) amending the L and Water Conservation Fund Act of 1965, which also established an independent Advisory Council with rulemaking powers, will important whenever archeological values ar involved. The National Environmental Poli Act, 42 U.S.C. § 4321, may also have an impact.

[4]United States *v.* Carter, *339 F. Supp. 1394 (1972).*

Although I cannot discuss individual ate laws in this paper, the Federal Acts y be duplicated at the State level, so at within each State, State laws must be nsulted because State law does vary between ates.

NAVIGABILITY

Before discussing the development of propriation law, it is important to consider the development of the law on naviga- e waters, or the extent of the jurisdic- on of the United States under the Commerce ause. A determination of "navigability" important for two reasons: (1) it affects e ownership of the bed, and (2) it has af- cted the jurisdiction of the United States. a river was "navigable" at the time a ate was admitted into the Union, then the ate has title to the bed. If it was not vigable, then the entity that owns the joining shoreline owns to the middle of e riverbed. Since the laws of the United ates control the disposition of its prop- y (*U.S.* v. *Oregon*, 295 U.S. 1(1935)), ether a waterway is navigable and title sses to the States is a question of Fed- al law.

The question of navigability for title important because although the public has lear right of recreational use of a "nav- able" water, its right of recreational use nonnavigable waters may vary from State to ate. The traditional view, based on En- ish Common Law, is that the owner of the d of a nonnavigable waterway has the ex- usive right of use of the surface of that ter. This has been followed in some ates, particularly as to lakes.[5] However, e view of most States is that the public s a right to use the surface of all waters, gardless of whether the bed is privately publicly owned. This rule follows natu- ally in those States whose constitutions clare all waters to be public waters.[3]

In *Day* v. *Armstrong*, 362 P.2d 137 (Wyo. 61), the court ruled that the public has right to float a craft down any stream, en if the banks and bed are privately ned. The court stated that this included the right to disembark and portage, if necessary to floating, but not if that were the primary purpose. This principle should be applied carefully. The existence of this public right does not mean that the public has a right to trespass across private land to get to such waters. Access to such waters, if nonexistent, must be legally acquired. Riparians and appropriators have other rights that must be respected, notwithstanding this public right.

The other reason "navigability" is important is that it determines the jurisdiction of the United States. While States may own the bed of navigable waters, their authority is always subject to the paramount power of the United States under the Commerce Clause. Under the English ebb-and-flow test, the jurisdiction of the United States would extend only to tidal waters. However, the courts in this country adopted the navigability test, which extended the jurisdiction of the United States to all navigable waters.

The courts have used various measures to determine navigability: whether logs have been floated on it, whether a fur trade was conducted on it, whether a light skiff may traverse it once a year, etc. The disparity in tests has led to a disparity in results. For that and other reasons, the courts may in the future utilize navigability to determine the jurisdiction of the United States as a measure less frequently.

The full extent of the jurisdiction of the United States under the Commerce Clause was most recently and significantly exercised in the Federal Water Pollution Control Act amendments of 1972, which refer only to waters of the United States. The Corps of Engineers tried to adopt regulations narrowly construing the statutory definition, but lost a judicial challenge to its regulations. Its subsequent revisions have resulted in congressional efforts to amend Section 404. The important thing in this review of the navigability questions is to recognize that the authority exists and to know the extent to which it has been exercised.

WESTERN WATER LAW

Finally, we get to the problems created by the particular development of western water law. The tremendous variations between the States preclude anything more than a general overview.

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[5]Proctor *v.* Sim, *236 P. 114 (Wash. 1925)*; sa Land Co. *v.* Burdick, *90 P. 532 (Cal. 07)*; Hartman *v.* Tresise, *84 P. 685 (Colo. 05)*.

Strict appropriation law provides that a person who diverts a certain amount of water and applies it to a beneficial use acquires a right to use that amount of water and does not recognize any other method for acquiring rights to water. It arose primarily because water was scarce and because appropriators had to be provided with some security that their investment of time and money would be protected in order to encourage development. Nine States (Alaska, Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming) have adopted strict appropriation law. Ten others have adopted the so-called "California doctrine," an admixture of riparian and appropriation law (California, Kansas, Mississippi, Nebraska, North Dakota, Oklahoma, Oregon, South Dakota, Texas, and Washington). Most States that follow the appropriation doctrine, in strict or modified form, have also adopted a permit system to regulate the use of water and prevent appropriations in excess of available water. The permit system provides some protection for a river manager in that a notice of application for a permit to withdraw water and an opportunity for public input are usually required. The statutes establishing the permit system usually provide the authorized official with certain preferences between beneficial uses and standards for acting on a permit application. Most provide that a permit application may be denied in the public interest.

Usually, the system under which the river manager operates contains both authorizations and prohibitions. The authorizations might be to protect the fishery; preserve wild, scenic, or other values; or require a certain minimum flow. Prohibitions would include barring the violation of existing rights.

The water already appropriated represents such an existing right, as does the right of private property owners adjoining the river who might be adversely affected by the nature or extent of the recreational use of the river, particularly if it were noisy, excessive, or resulted in unauthorized trespass on this land. The State may be required to regulate use resulting from its developments (*Botton* v. *State*, 420 P.2d 352, Wash. 1966).

The water previously appropriated is part of the existing situation encountered by the river manager. While it does present certain constraints to him, future appropriations, unquantified or excessive appropriations, and appropriations in the form of reservations are more significant for future river management. The effect of the reservation doctrine is discussed in the next section. The effect of over-appropriated streams may be mitigated if State of Federal law provides minimum flow requirements, prohibits all appropriation (as the State of Oregon did with the Rogue River), or provides that the creation of the system under which the river manager operates constituted a reservation of those waters. It is important to notice who is appropriating water for what purposes, whether and where that water will be returned. If the appropriation is for municipal water supplies, that may involve restrictions on the use of the waterway.[6]

In States that recognize both riparian and appropriation law, the riparian has no right he can assert that is superior to a prior appropriated use.[7] However, riparian rights will prevail as to a subsequent appropriator. In Washington, the amount of water in excess of that which can be used by a riparian within a reasonable time is subject to appropriation for use on nonriparian land (*Brown* v. *Chase*, 217 P. 23, Wash. 1923). California prohibits waste by either riparians or appropriators. In one case, the California court ruled that the pumping of water for a game preserve to attract wild waterfowl was a nonbeneficial use or waste of water.[8]

THE PROPERTY CLAUSE, THE SUPREMACY CLAUSE, AND APPROPRIATION LAW[2]

Congress clearly has the authority to dispose of waters on the public domain.[9] The first such attempt was the Act of 1866, 43 U.S.C. § 661, which provided that waters on the public domain may be appropriated as determined by local rules or customs. This was followed by the Desert Land Act of 1877

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[6]Clinton Water District *v.* Island County, *218 P.2d 309 (Wash. 1950).*

[7]Schodde *v.* Twin Falls Land & Water Co., *224 U.S. 107 (1912).*

[8]City of Los Angeles *v.* Aitken, *52 P.2d 585 (Cal. 1935).*

[9]United States *v.* Oregon, *295 U.S. 1 (1935).*

Gutierres *v.* Albuquerque Land & Irrigation Co., *188 U.S. 545 (1903).*

U.S.C. § 321, which the Supreme Court erpreted as severing water and land on public domain.[10] Although the United tes has the power to control the dispo- ion of waters on the public domain, it substantially left determinations of er rights to the States. An exception where the United States exercises its hority and apportions waters from nav- ble streams, as in the Boulder Canyon ject Act of 1928, 43 U.S.C. §§ 617-617t, ch was interpreted by the Supreme Court *Arizona* v. *California*, 373 U.S. 546(1963).

The Supreme Court may, in the case of a pute between two States over interstate ers, exercise its original jurisdiction apply a doctrine of equitable apportion- t, as in *Kansas* v. *Colorado*, 206 U.S. 49 07). Perhaps the most important feature ofar as appropriation law is concerned, the reservation doctrine. First enunci- d in *Winters* v. *U.S.*, 207 U.S. 564 (1908) extended in *Arizona* v. *California, supra*, essence of this doctrine is that the ted States reserves such water from ap- oriation under State law as is necessary accomplish the purposes for which the ervation was established. The actual ect of the reservation doctrine is un- certain because the extent is unquantified. The effect is probably greater where Indian reservations are involved because it is not certain what limits exist as to the use to which such water may be put. In Colorado, where the United States is in the process of quantifying its rights, a Master-Referee has adopted the position that the United States may, by establishing a reservation, reserve a certain amount of the instream flows for fish purposes. However, the Master-Referee ruled this was not achieved until the Multi- ple Use-Sustained Yield Act was enacted in 1960. An Idaho court has rejected the po- sition that the United States reserved the entire flow or even a minimum flow.[11]

In summary, I have attempted to provide a brief overview of the complex legal frame- work in which the river manager operates. As more laws are enacted, the framework will become more complex. There are some ques- tions I did not discuss, and some that have not been resolved yet. While litigation may be necessary to resolve some questions, I would advise you to avoid litigation whenever possible because it is expensive, ineffi- cient, not always successful or productive, and, perhaps most important, you can lose control over a problem when it becomes a subject of litigation.

[10]Federal Power Commission *v.* State of on, *349 U.S. 435 (1955).*

[11]Avondale Irrigation District, et al. *v.* North Idaho Properties, Inc. *(Dec. 1, 1975).*

INDUSTRY RESPONDS TO THE EXPLOSION IN RIVER RECREATION

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ABSTRACT.--Describes the response of private enterprise to the growing interest in river recreation--increase in number of outfitters and production of boats and gear as well as how publishers have created a literature of the sport and of the many new services that are provided the river-running public.

More than five times as many people floated the Snake River in Grand Teton National Park in 1975 (83,096) than in 1966 (18,174) (table 1). Only 2,068 people had floated the Colorado River through Grand Canyon before 1966. In 1966, 1,067 people floated it and in 1972 more than 16,000 people (16,428) did so. In Dinosaur National Monument commercial permits increased from 2 in 1967 to 14 in 1976. In the early 1970's, commercial outfitters on the Rogue in Oregon doubled, from 20 to 40.

Statistics on outfitters provide a true picture (table 2). For an outfitter in Ohio, passenger numbers skyrocked--from 100 to 5,000--in three years as he grew from a single-boat operation to one that hired 20 guides and ran 30 boats.

An outfitter on the Chattooga River stateline started his business in 1972 to take advantage of the publicity offered by the movie "Deliverance", which was filmed on the Chattooga. By 1976, he had increased from an original 8 guides to 18, the number of boats he ran had nearly doubled, and his clientele total had tripled.

In Dinosaur National Monument, commercial passenger numbers rose from 6,344 in 1970 to 21,612 in 1975. Several outfitters expanded their carrying capacity by using more boats, running more frequent trips, fuller boats, and, of course, hiring more guides.

The matter of ceilings, allocations, and limitations imposed on outfitters by administering agencies has slowed the trend in many areas. One outfitter writes "The rate of increase the past few years has been 20 percent due to limiting factors (drought, user day limits, the economy). Our biggest growth year was between 1972 and 1973,"--just when administrative limits were imposed.

A canoeing outfitter, in New Hampshire reports that in 1974 he started his business with only nine canoes. By 1976, his third year of operation, he had 50 canoes to rent. He now rents all kinds of river equipment, has a full outdoor shop relationg to river travel, conducts kayak schools and fully outfits canoe trips. He also runs three canoe and kayak races each year to stimulate business, and he has published three river maps. This outfitter is only one of four that began operating in the same area the same year (only one had served the area previously), and all are doing well.

In the Ozarks, the owner of a country store and gas station has begun renting canoes in the hope of selling more gas, groceries, ice, and beverages to river runners who haunt the area. An outfitter in Tennessee has expanded his services to include boat repair and rebottoming of inflatables. He also sells rafts, canoes and repair kits. His 3,000 clients, most of whom come from out of State, learn about his services from articles in local or regional newspapers and national magazines.

An outfitter in the Pacific Northwest who began his career as director of a university outdoors program, started his operation in 1973 with eight raft trips

Table 1.--*River use increase in Grand Teton National Park (1966-75)*

Year	Commercial users	Private users	Private user using canoe/kayak
			Percent
1966	16,610	1,564	--
1967	23,655	2,476	80 (trip registration data)
1968	21,775	7,848	--
1969	32,623	7,950	--
1970	47,589	[1]3,808	--
1971	62,119	5,917	--
1972	62,867	8,389	57 (trip registration data)
1973	67,912	[2]5,973	49 (trip registration data)
1974	[3]59,632	7,624	58 (actual count)
1975	75,300	7,796	--

[1] High-water year, several drownings on near-by rivers.
[2] High-water year discouraging private use.
[3] Impact of the energy crisis.

Table 2.--*Individual outfitter increases in number of passengers (1970-75), Dinosuar National Monument*

Outfitter	1970	1971	1972	1973	1974	1975
A	3,108	4,366	5,926	5,665	7,300	8,294
B	1,886	2,611	3,550	2,870	3,090	2,626
C	616	1,409	1,425	1,588	3,488	4,779
D	--	1,220	802	751	2,820	3,197
E	346	458	595	674	845	1,478
F	--	133	126	171	435	404
G	34	160	133	144	28	284
H	158	--	--	43	96	173
I	--	92	40	43	220	172
J	--	298	207	175	105	105
K	--	10	15	13	40	50
L	--	--	10	16	48	50
M	196	--	--	--	--	--
N	--	20	--	--	--	--
Totals	6,344	10,777	12,829	12,153	18,515	21,612

the Rogue. In 1974, he added four kayak schools. In 1975 he added two trips each on the Deschutes and the Owyhee. In 1976, he increased his business to 10 raft trips on the Rogue, 12 kayak schools (140 students), and added 2 trips on the Illinois and 6 on the Klamath in addition to the 2 trips each on the Deschutes and Owyhee.

A classical success story concerns two operators each of whom had his own float trip business and his own boat. Both were turning away business. They decided to go into a parternship on a third boat, hiring a guide to run it. In their third year, they entered a full partnership, hired 3 more guides, and carried more than 10,000 passengers.

Their business continued to expand, but boats were scarce. They designed their own, found a manufacturer to make it for them, and helped pioneer boats built specifically for river running. By the early 1970's, they were hiring eight guides a summer. Then they initiated a white-water trip just as white-water boating began booming. In the fifth year of their white-water business, they had 17 guides and had more than 36,000 passengers; for the first time, their white-water trips accounted for more passengers than did their scenic trips.

In the early 1960's, three young men began to run river trips on Pennsylvania's Youghiogheny. Going to school or working at part-time jobs during the winter, they ran commercial float trips during the summer months. They eventually became outfitters.

One of them moved to the New River in West Virginia and developed what has become one of the biggest operations in the East, selling the rubber rafts he designed for the area.

"About 1970-71 the Southeast started coming alive," writes Dave Demaree, who serves as a raft manufacturer's representative in Ohiopyle, Pennsylvania, at the most popular put-in on "The Chattooga, Nantahala, French Broad, Nolichucky, and several other streams started to attract major commercial operations."

Demaree also comments on the ceiling or limitation factor: "Many new outfitters would have started on or moved into the Yough if the State of Pennsylvania had not limited the commercial operation to the four existing outfitters. They each were limited to 3 trips per day of 80 persons each trip (960 persons per day)." The regulations were imposed to save the river from the tremendous impact of recreationists.

A sad note comes from Michigan, where they didn't regulate, where people pressures are too great. In a Department of Natural Resources publication called "Michigan Guide to Easy Canoeing", a comment is made that "A few rivers have become so popular that canoe traffic can be called congested, especially on summer weekends. The Au Sable, Pere Marquette, Pine, and Manistee are prime examples."

Use trends, while still growing in most areas, have slowed considerably in areas where administering agencies have imposed limiting factors, but unless those factors are carefully selected the river users will find ways of thwarting the intent if not the letter of the regulation.

Outfitters often see these factors as anti-business, as a means of thwarting the free enterprise system; however, administering State and Federal agencies consider them as protecting resources for future generations. A serious conflict has risen out of these differing points of view, but that conflict lies outside the realm of this paper.

Another way of looking at the response of industry to the growing interest in river recreation is through canoe rentals and sales. Grumman's Rent-A-Canoe Directory indicates an increase of more than 30 percent in canoe liveries between 1973 and 1975 from 426 to 560 (table 3). There is no certain way to differentiate between river and lake use in many cases, but location of the new liveries suggests that the increase is primarily on the rivers. The increase may be due in part to better research on the part of Grumman, but there is no doubt that the trend is upward.

No State had a decrease in number of liveries between 1973 and 1975; 3 new States added liveries, and 10 States remained the same (they are not listed in

able 3). Eight States--Alabama, Hawaii, daho, Mississippi, Nevada, New Mexico, klahoma, and South Dakota--had no canoe iveries listed in the Grumman Directory.

States having the greatest increase ere West Virginia (1 to 4), Texas (7 to)), and Vermont (3 to 6). In several tates the number doubled from 1 to 2 or 2 to · However, a number of States having a rge number of liveries showed remarkable creases too: Ohio (28 to 38), nnsylvania (28 to 39), Wisconsin (33 to), New York (50 to 64), and Missouri (27 34).

ble 3.--*Increase in the number of canoe liveries*[1]

tate :	1973 :	1975 :	Increase
			Percent
kansas	3	4	33
lifornia	7	11	57
lorado	0	1	--
nnecticut	7	8	14
laware	2	3	50
diana	13	14	8
wa	4	6	50
ntucky	1	2	100
uisiana	2	4	100
ine	14	17	21
ryland	7	8	14
ssachusetts	5	7	40
chigan	58	59	2
nnesota	32	37	15
ssouri	27	34	26
w Hampshire	8	13	62
w Jersey	23	26	13
w York	50	64	28
rth Carolina	3	5	67
rth Dakota	0	2	--
io	28	38	35
egon	0	2	--
nnsylvania	28	39	39
ode Island	1	2	100
nnessee	4	6	50
xas	7	20	186
ah	1	2	100
rmont	3	6	100
rginia	6	10	67
shington	5	6	20
st Virginia	1	4	400
sconsin	33	44	33
tals[2]	426	560	31.4

[1] ource: Grumman Rent-A-Canoe Directory
[2] tals include States not listed that owed no increase

Canoe sales are reflected to some extent by the number of dealers. The number of Old Town Canoe dealers increased from 316 to 346 between December 1974 and June 1976, a 6.3 percent gain. Several interesting trends appear from an analysis of the location of the dealerships. The South and Midwest both show substantial increases; both New England and the West show only moderate increases. However, Maine itself, in which Old Town is located, shows an increase of 8 dealers (from 23 to 31), which means that New England as a whole showed a decrease.

When you consider that the freight rates to ship canoes from Maine to the West are high, it may be that Old Town statistics are not valid in the West. Further, several canoe manufacturers have emerged in the West during the past few years: for example, Easy Rider (Washington), Wilderness Boats (Oregon), and Nona (California). The fact is that canoeing in the West is becoming tremendously popular.

Dave Demaree writes "The canoe and kayak industry didn't get moving until late 1972. With the good TV coverage of the white-water slalom in the '72 Olympics and the film "Deliverance", not to mention a couple thousand people each summer day seeing kayaking boaters on most Eastern raft trips, paddling sales increased greatly." He suggests that the biggest sales are made by backpacking stores in big cities but that "speciality stores are appearing at rivers like pro shops at golf courses".

Demaree claims that there is a surplus product because so many manufacturers have emerged and that "Grumman is now actively seeking dealers for the first time in 30 years". He notes that the canoe business "had been growing at the rate of 25 percent per year" for the four or five years before the oil embargo slowed things in late '73. Grumman is selling between 75,000 and 80,000 canoes annually.

Most canoe companies now produce white-water models. One company (Blue Hole) makes only a product designed for paddling in rapids. It is probable, says Demaree, that "Kayaking has two to four hundred backyard manufacturers actively competing with commercial producers".

The manufacturing of inflatable rafts has had an interesting history. Initially river runners, private and commercial, used the military surplus assault boats and bridge pontoons from World War II, but by the mid-1960's when the business began to explode these crafts were in bad repair and in short supply.

Many outfitters began to design their own boats, and had them produced in West Virginia by Rubber Fabricators. In 1972, B. F. Goodrich bought out this company and dropped boats ("too little sales, too many hassles" says Demaree). The foreign raft producers--Avon and Leyland in England, a number of Taiwan and Japanese manufacturers --began churning out the boats including hypalon rafts marketed by Campways in this country.

Then the Coast Guard stepped in, announcing that they would soon be regulating rafting on navigable rivers and would enforce the Jones Act, which says in part that no foreign-built vessel may be licensed to operate in the United States.

As a result American manufacturers had an incentive to produce boats. Several key management and technical people formerly with Rubber Fabricators left B. F. Goodrich, according to Demaree, to form a new company, Rubber Crafters of West Virginia which is producing "the same quality river rafts they made" before. Another West Virginian long involved in the raft-building business started a similar company called Mountain States Inflatables, Inc. On the West Coast, a company called Maravia recently commenced construction of inflatable boats suitable for white-water purposes.

Personal flotation devices (PFD's) have been a real headache to river runners, commercial or private, especially to kayakers. A dozen companies have mass produced ugly, bulky, uncomfortable jackets for years, largely to fulfill Coast Guard requirements on flat-water powerboats. Few boaters wear them and dozens of people are drowned annually because they refuse to use them.

Stearns Manufacturing Company has put style as well as safety into PFD's. It produces a complete line of vests and jackets.

Several other manufacturers have responded to the need for a comfortable, Coast Guard-approveable PFD that people will wear. One sold only 500 PFD's over a 3-year period, but it sold 8,000 in 1976. Others include Gentex Water Safety's Mariner, marketed for the first time in late 1975, and Maravia's Type V life jacket, which was developed primarily with the commercial outfitter in mind.

Many manufacturers of equipment have been in business for years, sometimes in related fields. For example, Coleman makes all kinds of gear and equipment that might be used on a river trip: stoves, lamps, jugs and coolers, sleeping bags and tents. Not all are specifically related to river running, but it is obvious from the number of Coleman items used on river trips that sales are up. New equipment is being introduced on the market every year.

The R. T. French Company, which sells instant potatoes, packaged gravies and sauce mixes, as well as seasonings, and of course mustard, reports that "we have been interested in the growth of camping and boating activities because so many of our products can be used so easily on outdoor vacations. Our response has been largely public relations oriented. We have developed special recipe booklets, made films for television use, and have engaged special personalities to appear on radio and television for the purpose of passing along camping hints and performing live food demonstrations."

Several freeze-dried food manufacturers cater to the river runner. Mountain House of Albany, Oregon, uses a photograph of a Grumman canoe (as well as one of the Voyageur waterproof bags) in one of their mail-order ads and order forms. Another supplier of lightweight foods--the Grover Company of Tempe, Arizona--recently displayed its goods and gave free samples at a meeting of the Western River Guides Association with good results.

A growing list of boats, books, and other river running accessories appear in the catalogs of mail-order houses: Gerry; Laacke & Joys; Eddie Bauer; Bushnell; The Great World of Ecology Sports; The North Face; Holubar; Frostline; Recreational Equipment, Inc.; Waters, Inc. and L. L. Bean.

L. L. Bean reports "We do sell a full line of canoes and inflatables (with a noticeable increase in sales of inflatable canoes). We also have a variety of valuable accessories such as Handyboy pliers, Supertape, waterproof bags, a canoe chair designed to fit over a keelson in an aluminium canoe, plus a multitude of others."

A few years ago waterproof bags were at a premium. Military surplus ammo cans, delousing bags, and the old reliable "Bag, Waterproof, Special Purpose" that came in several sizes were just about all that were readily available.

The Voyageur Enterprises of Shawnee Mission, Kansas, now offers a line of water waterproof bags made of heavy polyethylene fabric. These bags have seen service on canoe trips and commercial rafting expeditions. Today a number of good waterproof bags are available.

Ann Dwyer is the author of "Canoeing Waters of California". She also is an instructor as well as guide and outfitter. She founded a river running equipment outlet and mail-order firm and a company to manufacture waterproof river bags. She reported: "Five years ago there was one canoe rental in Northern California; now there are three. There are 3 stores in the Bay Area that specialize in canoe and kayak equipment; 5 years ago there were none." The first raft trip on the Stanislaus, was made in 1962; 32,000 people floated it in 1972.

A manufacturer in Southern California was asked by an outlet for river running equipment to develop a pump for the inflatable trade. He has now geared up for mass production of a high-quality low-cost pump.

A number of small family businesses have grown into highly successful ventures. Take Payson Kennedy's Nantahala Outdoor Center, for example. He writes, "I got started as a result of realizing that I was spending all my spare time backpacking, climbing, caving, and especially white-water paddling... I decided it would make sense to try to find a job that would enable me to enjoy these activities."

He and his wife bought a place that included a ten-unit motel, a small restaurant, and a gas station. They began renting boats and the auxiliary equipment that goes with river running, and reports that "about half of our restaurant and gas station business and about 90 percent of our motel business is from river runners." The Center has "the most complete selection of white-water equipment in the Southeast"; and it "has become the focal point of white-water activity and instruction in the Southeast". The white-water schools the Center initiated have simply skyrocketed (table 4), and Payson has contributed a chapter on "Raft Technique" to the book ALL-PURPOSE GUIDE TO PADDLING (Great Lakes Living Press).

In the past five years white-water schools have developed all over the country, some of them associated with colleges but many of them run by outfitters or dealers. The University of California, Berkeley, offered a course during the summer of 1976 called "Flow of

Table 4.--*Growth of business at the Nantahala Outdoor Center, Inc.*[1]

Year	Raft passengers	Canoe students	Kayak students	Boat rentals
1972	1,000 (est.)	50	1,050	75
1973	3,833	250	4,083	300
1974	5,804	600	6,404	765
1975	7,841	900	8,741	1,025
1976	11,000 (est.)	1,425	12,425	1,750

[1]Figures supplied by Payson Kennedy, owner and operator

the River: the theory and practice of river running". This included a weekend run down the American River. The University of Utah offered independent study credit in environmental education for a five-day raft trip down Cateract Canyon on the Green River in Canyonlands National Park.

Articles and features on river recreation have been appearing with greater frequency during the past decade. In 1975, an article in *Smithsonian* featured Martin Litton's Grand Canyon dories. *Southern Living, WomenSport, Outdoor Life*, and *Colorado* all featured river running articles in 1976, and *Sunset* usually runs a feature on river running in the spring issue. *National Wildlife* magazine highlighted recreational use of several wild rivers with a cover story by Dave Sumner. Many might recall the *National Geographic* article by the Craighead brothers several years ago. A movie made in conjunction with that article is still being rerun on TV.

Two river running magazines emerged in mid-1974, *Oar and Paddle* and *Down River*. The former went under in its first year, but the latter is well and thriving with nearly 10,000 subscribers. Initially published bimonthly, it is now a monthly.

Canoe, the official magazine of the American Canoe Association, and *American White-Water*, the journal of the American White-Water Affiliation, reach thousands of river runners six times a year. Between 1971 and 1976, the number of AWA affiliates nearly doubled from 76 to 146.

Consider the ads in those magazines and in others, the full color brochures that are printed for advertising, the river maps and guide books that have been rolling off the presses. A decade ago only Les Jones was producing river maps. Today there are maps for dozens of rivers and stretches of rivers.

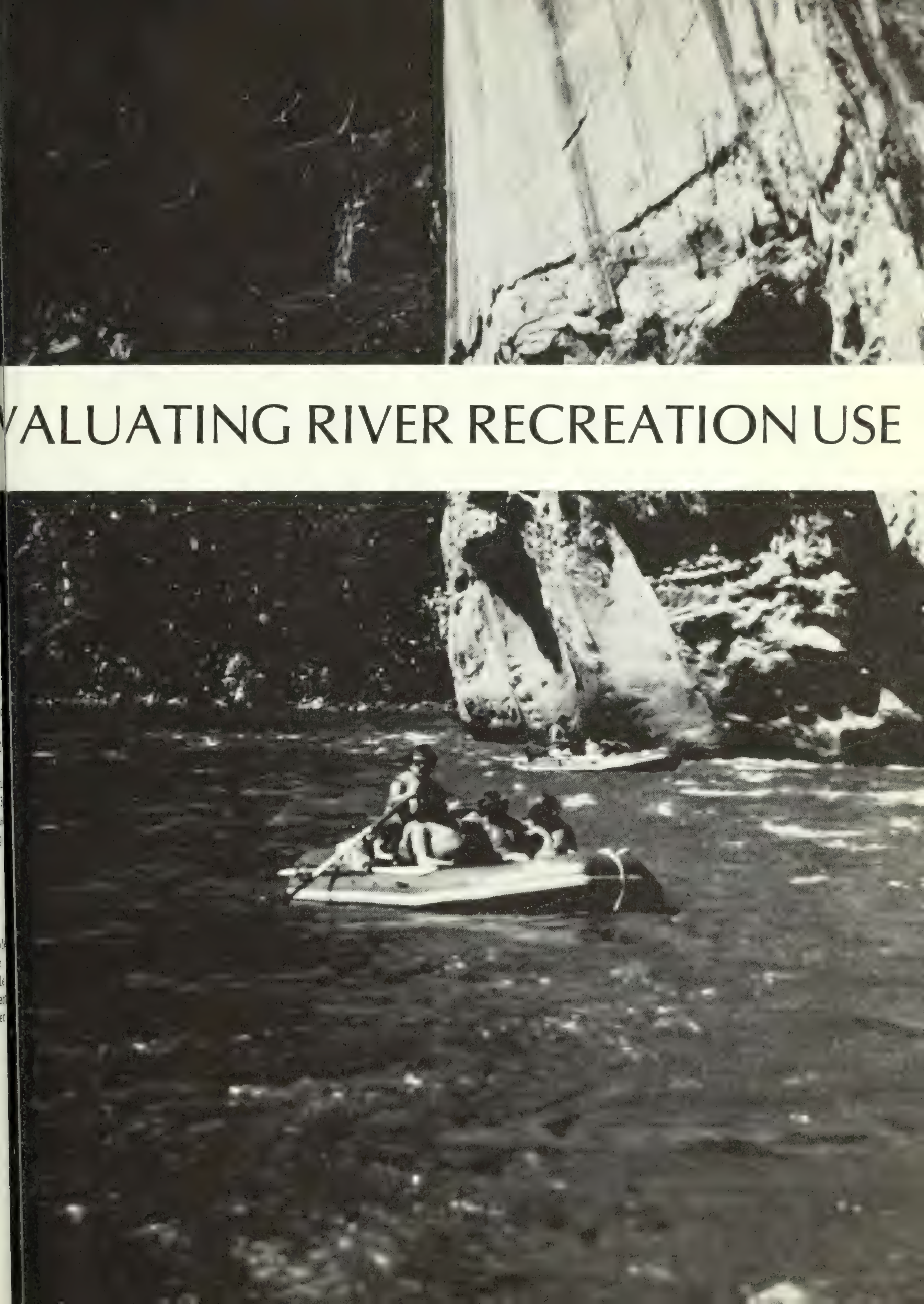
Dr. David W. Lime's "River Recreation Bibliography" (with Earl C. Leatherberry and Dorothy H. Anderson) reflects the amount of the material being published, largely in the past decade. No fewer than four books have been published on the subject since my book *River Running* came out 18 months ago. It sold 5,000 copies in the first 6 months. Bill McGinnis writes that his *Whitewater Rafting* "has sold about 5,000 or 6,000 copies". At least one mail order firm deals only in river running publications. Its list grows annually.

The interest in river recreation continues to grow. No doubt much of that growth has been created by the conscious effort of the outfitters and dealers in river equipment who advertise their services and goods, but word of mouth goes a long ways. So do magazine articles and features on television. The word gets around. No doubt my own books and articles have helped spread the word. I have mixed feelings about the part that I have played. So does long-time Utah outfitter Ken Sleight.

Ken writes philosophically, "I've stayed the same for many years--not much growth, leading my own trips--but my kids are guiding now, and our business has doubled. I can't say I'm happy about the growth of interest, but it had to come and many of us helped it along, sometimes to the detriment of the environment. I feel sad about it and a bit hypocritical. I guess the only thing now is to try to guid the planning and to lessen the impact. Bu the wilderness is gone--only scenic areas really remain but they are worth working for."

I agree with Ken, but some of the industry's response has had a positive effect: the river trips can teach people to care for the river resource and help lessen the impact. They can give people an appreciation for the river environment that can help save the rivers from other forces.

VALUATING RIVER RECREATION USE



RIVER LANDSCAPE QUALITY AND ITS ASSESSMENT

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ABSTRACT.--Illustrates the elements of visual assessment of river landscapes: (1) landforms, (2) vegetation patterns, (3) water presence and expression, (4) human use and impacts, (5) other influences. Discusses how to inventory landscapes at large and small scales of application, and with implications of planning and design policies. Points up problems (or dilemmas) of evaluating landscape quality using criteria such as of aesthetics applied to landscape, professional judgment, and perceptual studies.

Recreation quality and river landscape quality presumably go hand in hand. Looking at the whole river landscape and assessing it visually appears to be the best current means of suggesting its quality. Indeed such an overview, accounting for all of a river's connected landscapes, is considerably more practical than implying a measured assessment can be done.

Landscape inventories can summarize the various physical parts seen including landforms, vegetation patterns, stream characteristics, and their relations. Effects, impacts, and artifacts of human use and other influences, such as climate, may be added. A good, general sense of the present scenic resource should emerge from this procedure. It is correct to say we cannot do this now in a quantitative way. If this does become possible, through adequate research, it will be far in the future. Significant baseline information, including qualitative observations on aesthetic character and simple measurements, can, however, be provided. Useful comparisons along one river or between different streams can then be made.

It is not superficial to document the scenic resources of a river. It is an overview that speaks for the integrity or unity of the river landscape. Additionally, the visual landscape record implies, with further research, further linkages to environmental quality and to sociological and psychological perceptions.

ESTHETIC CRITERIA

The landscape is always complex. It is set with variations and details to trap the observer who would make evaluations. Because this paper is based upon an application of esthetic criteria, they are introduced now. A brief review follows, using my interpretations as applied to the landscape (Litton *et al.* 1974).

Basic esthetic criteria are unity, variety, and vividness (Pepper 1937). Each criterion is complex by itself, but when esthetic merit is present, all three are necessarily in evidence. Paradoxically, the criteria are in potential conflict; yet their balance is essential. Unity is that characteristic whereby all parts are joined into a single and harmonious whole. Total, dominant, or an apparent structure is made up of subordinate parts. Variety indicates the complexity of different and numerous parts--"richness" or "diversity" carry the same idea. Mere presence of various parts, however, is no measure of quality. Vividness is the characteristic that gives a strong visual impression. It indicates relations or combinations that are conspicuous. Contrast is a primary expression; another is more subtle: compositional reinforcement from repeated groupings or from somewhat similar aggregations.

Vivid landscapes and those with greater richness are usually equated to higher quality, unity being present. Perhaps the

are only the easiest to recognize. Placid or ordinary landscapes also have levels of quality, expecially important because they are compared to those called vivid. Regional significance and areal unity enter here, such as the unity--beginning to end--of a free flowing river and the amenity it provides to a region.

ELEMENTS OF LANDSCAPE ANALYSIS

Study of water and its attendant landscape pose difficult choices of what to consider, what to omit. It is clear enough, however, that an inventory and assessment of river landscape cannot look at the river alone. The physical landscape and relations readily seen are chosen here as limitations, following principles and restrictions used in WATER AND LANDSCAPE (Litton *et al.* 1974). Focus is also directed to rural rather than urban situations.

The three most tangible parts of the native landscape chosen for analysis are landforms, vegetation patterns, and water presence and expression. Other natural influences need recognition as they assume importance, including visual effects of climate, seasonal change, topographic orientation, and relative elevation. Finally, the evidence of human use and impacts will show, for better or for worse, and is added to the list. Omitted is what, for some, must be the most important part of recreation and the river landscape: animals, birds, and fish occupying their particular niches. The omission recognizes the subject as worthy of consideration in its own right but is also based upon the transitory, fluctuating character of animal-landscape relations. Analytical elements chosen seem, within the bounds of usual human experience, relatively enduring despite recognition that the landscape is indeed dynamic.

Landforms

Landforms, as related to streams, are essentially containers--envelopes of space. I have also called this the "enclosed landscape" (Litton 1968). The degree of enclosure may be marked, as seen in the Yosemite Valley, or subtle, like the flattened saucer made by the Platte wandering over the High Plains. The steeper and higher enclosure makes a more vivid landscape (fig. 1). In comparative analyses, it is comprehensive to think of landform enclosure as a continuum from very steep and high with narrow defile to flattened and low with broad bottom. Simplifying, a set of three landform categories, mountainous, hilly, and flat plain (and plateau) may serve as inventory elements (fig. 2).

A regional inventory interpretation for differing types of landforms with representative streams might reveal that only hill-like enclosures existed. Then a more elaborate set of hill categories would be called for, defining differences of scale, relative height, side slopes, and ridge contours. Linton (1968), for example, in his scenic evaluation of Scotland identifies six landform categories. A somewhat similar study of the Northeastern United States (Res. Planning and Design Assoc., Inc. 1967) identifies 7 categories but with the additional detail of 23 subordinate landform types. And if a detailed inventory of only a small stream is made, landform definitions need to reflect the local variations.

Landforms are the landscapes's backbone, but apart from enclosure, certain parts may also be dominant visual features. Four conditions produce such features, applying both to single or grouped peaks. They are: (1) having isolation, (2) having dominant scale--being materially larger in relative size, (3) having contrasting skyline or silhouette, (4) having contrasting, conspicuous surface pattern. El Capitan is an obvious feature of the extraordinary Yosemite Valley enclosure, but bluffs of the Des Moines River are also significant features of that particular river landscape.

Vegetation Patterns

In the broad view, vegetation patterns emerge from the mixture of general cover types: forest, woodland, scrub/chaparral, grassland, and barren areas. Amounts of different vegetation types, their location relative to one another, position upon the terrain, and linkage to streams play a variety of visual roles in the landscape. Dominance of one kind of cover may be the typical expectation: Appalachian hardwoods, Cascade conifers, Dakotas' grassland, or sage-scrub of the Southwest. This implies a degree of monotony. The whole overlay of plants tends to function as a unifying blanket while at the same time being made up of many and complex individuals (fig. 3). Closer examination of the plant mosaic, especially related to landforms and rivers, will reveal tangible ways it enlivens what we see.

Figure 1.--*White water feature within striking mountainous enclosure with supporting conifers in the riparian zone.*

Looking at a sample of enclosing landforms of the Rocky Mountains, we would expect lodgepole pine or spruce-fir to occupy intermediate slopes, sometimes continuously, sometimes in patches and stringers. Grass will likely make up the patches, and aspen stringers on more moist sites join those of pine. Above, steep barren surfaces or those scant with forbs add an earth color to the greens. In the bottom, a sedge meadow, perhaps with aspen rim and oxbow concentrations of gray willow, add to a vivid yet calm mosaic. Differing amounts and shapes of cover with contrasting textures and colors mix together: light smooth grass, dark upright conifers, intermediate earth tones, and greens of riparian hardwoods.

Although the vegetation patterns of the Rocky Mountains undoubtedly provide strong visual images, some local expression will be apparent wherever we go. The ripa ian zone, its edges joining the river and margins of vegetation on higher ground, is the special place most apt to contribute distinction. The meandering string of cottonwoods along the Platte provides more enclosure than the land itself and can be more visually dominant than the water it follows. Or birch and granite margins of streams connecting Wisconsin lakes, backed by spruce, are the more conspicuous parts of that plant pattern.

Plants and cover patterns in the rive landscape are usually subordinate to the basic landform and water elements they join. Their visual role can, however, be strong and perhaps dominating, occasionall becoming distinct features or functioning to define space. Seasons, too, can give t plant mosiac its time of dominance.

Figure 2.--*Sinuous, quiet stream, visually dominant and continous through junction of contrasting steep hill and flat enclosures, significant farmland pattern.*

Water Presence and Expression

Most people living inland expect their surroundings to be primarily dry land, not water. Rivers are relatively scarce but perhaps clearly so only in arid places. Minnesota calls itself "the Land of Lakes," and Scotland is well known for its lochs. Similar claims do not seem to have been made for places calling themselves "lands of rivers". The presence of rivers does suggest a special source of landscape amenity, even while occupying a proportionally small bit of the whole terrain face. Water in the landscape tends to be dominant because of its visibility, its movement, reflections, and color, its consequent contrasts to adjacent earth surfaces. Loren Eisley (1959) suggests other complex and deep seated values: "If there is magic on this planet, it is contained in water."

River patterns and linear expressions of water, particularly as they may be related to landform enclosures, provide initial and larger scale means of visual analysis. Four patterns, four paths of water across the land, are braids, meanders, sinuous, and straight reaches (Leopold and Wolman 1957). An area or unit of relatively consistent landform enclosure may be accompanied by a single reasonably consistent reach of stream (fig. 3); there can be as readily a combination of dissimilar, contrasting reaches. Leopold (1962) has emphasized the great variability of rivers and their patterns, despite their "--pervasive unity--".

Figure 3.--*Reflective meandering stream in broad grassland bottom, gentle slope enclosure with grass cover and farm woods.*

More detailed visual definitions--secondary patterns--come from a stream's differential movement within path patterns. White water, the roaring, fast expressions of vertical falls and steep gradients, is the most distinctive water element (fig. 1). Quiet, placid, and slow moving water, dark in color, occupies the other end of the landscape expression (fig. 3). Between these extremes are all the other kinds of movement: segments that are swift, boiling, swirling, turbulent, or rapids and riffles. Degrees of disturbance and combinations are infinite, calling for careful observation and astute judgment as to landscape effect.

After path pattern identification, falls, cascades, and rapids can be sorted out as dominant features. A still, deep pool can also be a feature, apparent for contrasts of greater disturbance above and below it. Clean-cut features may be absent. Certain combinations of segments with differing kinds of movement and lengths are, however, specific visual expressions of specific streams. Meander sets, for example, may be joined by riffles or long straight runs by simple curves.

Beyond the river, linking land and water, riparian vegetation can be noted for vividness of contrast or simple continuity and unity. Sinuous or meander stretches are apt to be close crowded by willow or other broadleaf trees. A swift reach can force trees to stand back, tolerating only minor sandbar plants nearby. Each combination adds to or subtracts from the visual image of the water element in the landscape.

Human Use and Impacts

Human use can produce patterns that are mfortable with the river landscape. Agri- lture is one use apt to fit this way, ether along the Dee in Scotland or in rtheastern Pennsylvania (fig. 2). Oppo- te effects can result with unfortunate se, giving visual impacts of variable gnitude. Mining with unreclaimed leavings poorly designed recreation facilities, pecially near water, have high potential r landscape degradation. It is, none- eless, a mistake to presume that landscapes higher quality are only related to their gree of naturalness. Human use, reflecting od planning, design, and maintenance, can mplement the landscape in desirable, tisfying ways.

Agricultural patterns are primarily om changes in vegetative cover, frequently ometric, frequently more open than what s replaced. Topography is seldom altered her than in minor ways. Because farming pends upon maintenance of plant covers, tends to fit surrounding vegetation. cupation of flatter rather than steeper opes reduces the visibility of change.

Forestry has a wide range of potentials r fitting the landscape as well as peri- ic disruption (fig. 4). Selection cut- ng makes subtle visual modifications; clearcutting is--or can be--obvious. Steeper upland slopes are normal sites, places where changes are more conspicuous as compared to flatter ground. Apart from roads, topo- graphy is little altered. Geometric pat- terns are typical, the fit to landscape can be good, bad, or indifferent. Good forestry does aim to maintain full cover on suitable sites; the activity is most appar- ent when cover is absent.

Mining and quarrying are apt to produce strong visual contrasts and accompanying impacts. Topographic and grading altera- tions are characteristic. Geometric hand- ling of leavings, with form and color con- trasts, are obvious. Vegetation is cleared and replacement may be exceedingly difficult because of inhospitable conditions.

Recreation facilities usually occupy only small parts of the river landscape, but you can be sure that interesting places are involved where people wish to be. Structures about the waters' edge occupy a most vivid part of the landscape, the land-water junction. Back shore areas are less sensitive. Well conceived design of facilities is essential here, following after suitable planning for appropriate uses and locations (Litton *et al.* 1974). Proper maintenance is also critical for such sites.

Figure 4.--*Straight, swift stream reach within gentle slope enclosure, land- forms visually strengthened by con- tinuous conifer forest.*

This paper cannot address the many ways in which well planned and designed human use may best fit the native landscape. It is possible, however, to summarize certain factors that have to do with the landscapes' visual vulnerability to use impacts (Litton 1974). Skylines and waterlines are highly vulnerable places; areas amid surface slopes are less so. Landscape features and other compositional types are sensitive to change (Litton 1968). Grading and associated soil color contrasts are more obvious than vegetation manipulations. Complex plant mosaics offer more camouflage to alterations than do pure stands of plants. The scale of changes needs to be appropriate to the surroundings. Small changes can be odious, larger ones can actually be more suitable and fitting.

Other Influences

Climate, seasonal change, topographic orientation, and relative elevation are selected examples of other influences affecting landform, vegetation, and water, and the way the landscape will look. Regional considerations will result in rejecting certain influences and substituting others.

Climate, marked by much precipitation or little, can result in frequently encountered perennial streams or their relative rarity. Vegetation follows suit--lushness or sparsity attended by entirely different textures and colors. Within the general climate of a broad area, microclimates are at the heart of landscape variations, particularly through soils and associated plants.

Seasonal changes bring profound changes to some landscapes, little to others. The extensive bright foliage colors of the Appalachian autumn have no counterpart in the West. Or, as with microclimates, local pockets of variation can set visual patterns. Even in places where vegetation seems to respond little to time of year, shifting occupancy of animal and bird life can bring delicate, perhaps elusive, landscape modifications.

Topographic orientations can be associated with several different visual effects. One, in the northern hemisphere, is that southerly slopes have greater visibility than do northerly ones through receiving more direct sunlight and in greater amounts. Another is the response of vegetation, again with climatic linkages. Grass-forest patterns of the West or conifer-hardwood patterns of the East are partially traced to orientation contrasts.

Elevational differences, if sufficient, can be related to many changes of landform, vegetation, and water expression. Tracing the Missouri from Rocky Mountain origins and across the Great Plains is accompanied by overwhelming changes seen in the landscape. Riverscapes within the bounds of single States, say Michigan or Nebraska, demonstrate relative consistency and modest variations.

VISUAL INVENTORIES

The scales at which landscape inventories are made depend upon purpose, whether to serve broad area planning or discrete area design and management. One generalizes, the other provides a desired level of detail. For our purposes, inventories are the base from which river landscape quality comparisons may be made.

Landscape inventory methods depend heavily upon visual kinds of data. These are topographic maps, high altitude imagery, conventional air photos, and field work. For authenticity and tangibility, field observations with resultant documentation are absolutely essential. These include mapping, low-level air and ground photography, and sketches.

Inventory types are Landscape Units, Setting Units, and Waterscape Units (Litton *et al.* 1974). These constitute recognizable visual entities from larger to smaller scale and serve as models adopted here.

Larger Scale Application

The Landscape Unit is based upon regional similarities (or consistencies) of terrain, vegetation, and water elements. Despite internal variations, we have--crudely put--a "homogeneous landscape". Boundary limits occur as consistencies disappear. The Unit is large, never seen all at one time. Memory plays a part. Low-level air observation and photography are vital aids. High altitude imagery (ERTS, Skylab) are appropriate tools as are smaller scale topographic maps at 1:1,000,000 to 1:250,000 scales.

The value of the Landscape Unit is its ocus on the broader landscape and an overll sense of regional landscape quality. 'he evaluation of individual river landscapes and planning for them can be appraised in a regional context.

Smaller Scale Applications

The Setting Unit is essentially defined y its visual corridor--the envelope of pace referred to earlier. Its limits may e plotted on a map in the field or by computer graphics (Amidon and Elsner 1968). t is a segment of one river landscape with easonably consistent or recognizably simlar relations of topography, water, and lants. This unit is not necessarily isible all at one time--but it may be. ntermediate in size, contour maps of :250,000 to 1:24,000 suit the units' tudy. Low-level air photography is highly esirable, and ground photography is ssential.

Usefulness of the Setting Unit lies n its tangibility. Characterized by midle distance views, a set of these Units rovides a means for comparing landscape ualities along a single river. Settings an assure that design and resource mangement respond to locality.

The Waterscape Unit focuses upon the iver, water patterns and expression, and he immediate riparian zone. It can be art of the stream within a Setting Unit ut may extend beyond as well as be coinident with the setting. Topographic maps t 1:62,500 to 1:24,000 and larger scale re appropriate. Ground studies and photoraphy are necessary. Design and resource anagement at site scale and as intimately elated to stream character is served by his Unit.

PROBLEMS OF ASSESSMENT

Criteria, semantics, limited research, nd resource-management needs pose problems n landscape assessment. Yet, interesting pportunities accompany the problems.

Criteria sweep together a set of diemmas. There are no universal, complete, r wholly agreed-upon standards of judgent. Probably there never will be. Crieria may be esthetic, physical, psychoogical, or sociological--or combinations f these. They come from professional studies by geologists, engineers, landscape architects, geographers, and planners as well as from scientific research by economists, geomorphologists, geographers, psychologists, and sociologists. Much research looks for responses and preferences from lay insight. Agencies want and need to know what the public thinks--more sources of judgment. Administrative needs temper criteria and add certain of their own.

Semantics enter landscape evaluation with the mixture of disciplines that work with it. This does, of course, make for thoughtful interchange and brings different professions into contact. There is no standardized vocabulary for landscape definition although recent USDA Forest Service publications move in this direction (USDA Forest Service 1973a, Schwartz *et al.* 1976). Everyday language is the basic tool. Understandings vary and definitions need to be provided. Even so, my definition of "landscape feature" easily goes astray. And the "sensitivity levels" used by the USDA Forest Service and the Bureau of Land Management are different, yet related. The landscape's very complexity must also contribute to the problem of words used in its behalf.

Research in landscape analytics, what little there is of it, is new. Most of it has appeared in the past 10 years. Related recreation and leisure-time research is not particularly tied to identifiable landscape characteristics but may give useful insight to scenic values. Most research is regional. Boster's (1973) study of Arizona ponderosa pine forests and Zube's (1974) study of Connecticut River scenic resources are primarily valid for those areas. Caution does not allow casual interpretations for use elsewhere. Wilderness, agricultural landscapes, and highly variable wildlands are backgrounds for research; it follows that conclusions must vary accordingly. Much remains to be studied.

Resource management has needed landscape evaluation techniques in advance of adequate research. This has at least put research to test and administrative means of application have also been developing. Understandably, administration would like quantitative evaluations of landscapes and potential impacts but must settle now for comparative devices. One result has been the use of arbitrary numbers to represent

judgments about landscape quality or sensitivity to visual change. Such numbers can be no better than the criteria behind them nor the professional application made of them. Federal guidelines for visual landscape management in the USDA Forest Service (USDA Forest Service 1974a) are used in drastically different situations. Regional interpretations are necessary. What is good for Alaska has little to do with New Mexico. It is another task, welcome no doubt, for the landscape architect. Management needs, nonetheless, do suggest a healthy climate for research.

CONCLUSION

Enough unresolved problems and opportunities in landscape assessment research and management exist so that complacency should not be a threat. The procedure given here has emphasized visual documentation of the river landscape's continuity. This is a proper context within which quality may be judged. Evaluation concerned only with high quality segments of landscape misses the essence of the problem. The goal, both of evaluation and later management, needs to be maintenance of the river landscape's integrity.

IMPACTS OF RIVER RECREATION USE ON STREAMBANK SOILS AND VEGETATION — STATE-OF-THE-KNOWLEDGE

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ABSTRACT.--Various means of assessing recreational impacts on streamside soils and vegetation have been employed to provide data to support and implement management decisions. Paired or before-and-after use plots and transects have generally been used to measure changes in the specific composition and density of vegetation, soil compaction, erosion, available moisture, surface soil cover, etc. Changes in the soil and vegetation have generally been related to intensity of use. Past research in this area has usually been confounded by several problems. Among the most critical needs are: (1) selection of sampling points or sites to yield impact data representing an entire riverway; (2) the random location of plots, points, and transects within a selected area; (3) the location of suitable before-and-after or used-and-unused sites for control; (4) the selection and measurement of the most important and most user-sensitive soil and vegetation parameters; and (5) the measurement of visitor use and its correlation with impact data. Management decisions based on this research must be limited by how well the investigator has dealt with these problems.

To agencies charged with providing and maintaining high quality recreational opportunities for ever-increasing numbers of people, the illusive carrying capacity concept is of more than academic interest. Resource managers are increasingly aware of the need to match and even regulate user numbers to coincide with the ability of the natural attraction to hold up under the impact of sustained recreational pressures. Managers can no longer live with the idea that it is their responsibility to provide a steady flow of recreational opportunities of optimum quality for an unlimited public, regardless of the cost. Each site has a level of use beyond which the resource characteristics or the quality of experience are adversely and permanently changed. How many people using a particular site for a set of special purposes over what period of time will finally degrade the resource to a level that is unacceptable to the recreationist?

Research into carrying capacity has generally taken two distinctly different routes depending, it seems, on the training and the bent of the investigators. Most studies have been sociological and have attempted to assess public attitudes toward various levels of use, resource deterioration, or both. This group of studies has attempted to answer the question: what, in general, is the maximum tolerable level beyond which the quality of experiences declines to an unacceptable point? This tolerance level varies among recreationists and, indeed, among managers so that determining just what is unacceptable in each situation becomes difficult. The other research route is more resource-oriented and has attempted to quantify the changes brought about in specific environmental factors by various levels and types of recreational use. In the resource-oriented studies researchers have almost universally directed their attention to the most noticeable changes that generally occur to the

soil and vegetation as a function of visitor traffic and associated activities. Both routes of study can yield useful management information.

The balance of this paper is devoted to a review and discussion of some of this past research, particularly as it applies to river recreation. Research approaches will be outlined and a summary of the principal findings will be presented. Finally, some discussion will be devoted to the interpretation and application of the results of these studies.

RESEARCH OBJECTIVE AND METHODS

There are basically three approaches to measuring recreation-induced changes in the soil and vegetation. By far, the most desirable is the before-after method; i.e., obtain soil and vegetation data prior to opening up an area and then inventory the area after some period of use. A convenient alternative to this method is to establish a set of sampling plots and transects in the used areas and locate a similar but undisturbed area nearby for an identical set of control plots. Third, recreation areas may be surveyed, without employing controls, to obtain impact camparisons between different types and intensities of use, frequently on areas exhibiting different native soil and vegetation characteristics. There have been variations. Each approach yields useful information if the results are properly interpreted.

Soils

Soil compaction from visitor traffic has been the most frequently inventoried variable. La Page (1967), Magill (1970), McCool (1969), and Merriam and Smith (1974) used penetrometers while Frissell and Duncan (1965), Meinecke (1928) and Ripley (1962) used infiltration or hydraulic conductivity measurements as an estimate of this variable. Dotzenko *et al.* (1967), Lutz (1945), and Settergren and Cole (1970) employed gravimetric techniques. Settergren and Cole (1970), and Sutton[1] used a portable nuclear gauge to determine compaction.

Changes in other soil characteristics have also been investigated. Root exposure and soil profile truncation that are direct results of the removal of ground cover vegetation, soil compaction, and sheet erosion, were studied by Cole[2] and James and Ripley (1963a). Organic matter, bulk density, moisture content, and other common soil parameters have been measured by Dotzenko *et al.* (1967), Merriam and Smith (1974), and Settergren and Cole (1970). Hansen (1975) studied the extent and cause of streambank erosion along the Pine River, a heavily canoed stream in Michigan.

Vegetation

A number of studies have examined changes occurring in the native tree and ground cover vegetation as a result of recreational use. The common approach has been to employ a system of plots of varying size and configuration for inventorying the tree cover. Point sampling transects and quadrats have been used to sample ground cover and the lesser vegetation. Where research objectives permitted a longer study duration, permanent plots and transects have been established to periodically monitor the seasonal changes and, frequently, intensity of use.

Cole[2] de Vos and Bailey (1970), Echelberger (1971), Frissell and Duncan (1965), Herrington and Beardsley (1970), Hinds (1976), Magill (1970), Magill and Nord (1963), Ripley (1962), and Sutton[1] have investigated various aspects of tree mortality (sometimes by species and age class) and decline in apparent vigor resulting from mechanical injury, heavy user traffic, soil compaction, and root kill.

The impact of concentrated recreational activity on the ground cover, and ground cover vegetation density and species composition has been studied by Cole,[2] de Vos and Bailey (1970), Frissell and Duncan (1965), Herrington and Beardsley (1970), La Page (1967), Magill and Nord (1963), and Ripley (1962).

Finally, Beardsley and Wagar (1971)

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[1] *Sutton, Steven W. The impact of floaters on the Ozark National Scenic Riverways. Unpublished Master's Thesis. 152 p. School of Forestry, Fisheries, and Wildlife, University of Missouri, Columbia.*

[2] *Cole, Dennis Michael. Recreational impact on forest sites in the Missouri Ozarks. Unpublished Master's Thesis. 103 p. School of Forestry, Fisheries, and Wildlife, University of Missouri, Columbia.*

lated amounts of herbaceous ground cover
l the growth rates of trees to various
nbinations of three cultural treatments
atering, fertilizing, seeding to grass
l clover), to visitor use, and to selected
te factors. Thus, they test vegetation
nagement as a means to maintain site
ality.

SELECTED RESEARCH RESULTS

The impact of concentrated recreational
tivity on the various soil and vegetation
rameters examined has varied with: (1)
e type, intensity, and duration of use;
) the nature of the existing environmental
ctors; and (3) the type of vegetation
nagement. Some of the general trends are
umerated below. Where a study has provided
formation specifically on river recreation
pacts or results that may be directly
plied to the management of our riparian
nes for recreation, some expanded coverage
given.

Changes in Soil Characteristics

The most common recreational impacts on
e soil include the following:

1. Surface compaction and bulk density
increased. The finer-textured soils display
the greatest degree of compaction. Sutton[1]
working along the Current River in Missouri,
noted that it was virtually impossible to
alter the density and structure of the gravel
and sandbar soils at stopover points along
the river frequently used by floaters. He
further observed that, with the possible
exception of occasional mechanical injury
due to the young willow vegetation by
visitors, these sites appeared to be in-
destructible.

2. The greatest degree of soil compac-
tion occurs immediately following the
opening of a new area. Thereafter, surface
soil density stabilizes.

3. With surface soil compaction and
the reduction in protective ground cover
vegetation (noted below), sheet erosion,
soil profile truncation, and root exposure
often result. Neither Hansen (1975) nor
Sutton[1] could attribute streambank erosion
simply to canoe traffic on the riverways
studied. The erosion that was measured was
usually linked to some nonfloating activity.
On the Current River in Missouri it was the
free vehicle access to the water's edge that
frequently led to serious erosion problems.

4. Infiltration and hydraulic con-
ductivity are reduced.

5. Soil organic matter is reduced.

6. Because of the effect of compaction
on infiltration and soil storage, soil-
moisture content and availability may be
seasonally low.

7. A few scientists, including La Page
(1962) and Meinecke (1928), found that frost
action during the winter months, when there
is little or no recreational use, loosened
the compacted surface soil aggregates to
some extent.

Vegetational Deterioration and Adjustment

The response of the native vegetation
to concentrated recreational use may result
from direct physical or mechanical injury
or may reflect physiologic and morphologic
adjustments made by the plants to soil
compaction, lower soil moisture, etc.
Among the more commonly reported observations
are:

1. Mechanical injury to most trees on
heavily used areas is common. Although
disease in wounded trees is a frequent
byproduct, mortality--except in extreme
cases and with certain particularly suscep-
tible species--is seldom inevitable.

2. Total elimination of trees in the
younger age classes, i.e., the seedlings
and young saplings, may result from seedbed
compaction and mechanical injury.

3. A decline in tree vigor frequently
signaled by "stagheading" may be associated
with soil compaction and root dieback.

4. One of the first environmental in-
dicators of heavy recreational impact is a
reduction in the native ground cover both
in amount and the number of species repre-
sented.

5. A number of investigators have
observed that, following the first few sea-
sons where the ground cover is reduced by
recreation traffic to some low point, there
is a recovery or adjustment in the vegeta-

tion (de Vos and Bailey 1970, Frissell and Duncan 1965, La Page 1967, Magill 1970, and Sutton[1]). There is a shift, according to La Page (1967) and Sutton[1] toward more recreation-tolerant species. However, the total number of species is reduced. Bluegrass (*Poa pratensis*) and path rush (*Juncus tennis*) were the most commonly found species on heavily used areas along the Current and Jacks Fork Rivers in the Ozark National Scenic Riverways by Sutton.[1] The rush is often an early indicator of heavy traffic along pathways. The grasses generally appear to be more resistant to trampling than the other, more herbaceous, ground cover species.

6. Beardsley and Wagar (1971) demonstrated that, with new areas, careful site selection and campground design coupled with reinforcement of heavy-use areas can substantially reduce or eliminate deterioration of ground cover vegetation. They also found that, under certain conditions, watering, fertilizing, and seeding to durable species can effectively increase ground cover on recreation sites.

DISCUSSION

There is little question that research has demonstrated that concentrated recreation will alter the soil and vegetation to some degree and that directed management can aid in counteracting adverse impacts. However, recognizing these effects is only a beginning. Correctly interpreting the research, i.e., placing things in the proper perspective; relating these results to some assessment of the intensity of use; and applying this information in a field situation require considerable additional management expertise.

INTERPRETING IMPACT RESEARCH

Recreationists do not "use" the entire site uniformly. Generally, they tend to congregate at and move along specific sites and routes; i.e., picnic benches, barbeques, boat launches, sanitary facilities, scenic attractions, and the straight-line paths between. The impact of use on the soil and vegetation is greatest, if not exclusively, on these sites of concentration. Researchers tend to sample use-related soil and vegetation changes on these obviously impacted locations. Research results tend to answer the question, "What is the magnitude of change or alteration on impacted sites?" This tends to generate data that will almost certainly indicate that recreational use adversely alters the soil and natural vegetation. This approach frequently avoids the question of how much of the *total* soil and vegetation resource is adversely impacted. Moreover, with river recreation, these impacted areas may be sparsely scattered along many miles of waterway.

Changes in the streamside soils and vegetation could be easily documented in a study of a number of sites along the Current and Jacks Fork Rivers in the Ozark National Scenic Riverways.[1] All sites selected for study initially displayed some signs of use. In relation to the entire 140 miles of rivers in the system, the impacted areas, the developed landings and access points, campgrounds, convenient gravel bars, caves, springs, and other attractions, represented only a very small percentage of the total resource.

It is the agency manager's responsibility to place things in perspective. He must evaluate localized adverse impact in terms of the total area. Furthermore, the importance he assigns to problems of site deterioration rests not only on how much but also on where specifically the impacts are occurring.

Relating Recreational Impact to Use

Since recreation management agencies must consider the cause as well as the effect of these impacts, they must attempt to relate changes in the various soil and vegetation parameters to the number of visitors and the type of use. Only a limited amount of research has been done on this aspect. La Page (1967) computed the regression relation between percent cover loss and camper days. Merriam and Smith (1974) calculated impact stage values from inventory data that included measures of bare soil, loss of ground vegetation, soil compaction, dead trees or trees with exposed roots, and increase in site size. The inventory data were obtained from newly developed campsites in the Boundary Waters Canoe Area. They related the impact stage values to visitor days, again by way of regression analysis. Some researchers have found that, following an initial change in the soil and vegetation, very little additional impact results with increased use (Frissel and Duncan 1965).

More studies incorporating an assessment of the cause, (a quantification and classification of users) as well as the effect, (a measurement of the changes in the natural environment) are needed to provide the tools for the resource manager to fully understand and cope with the problem. If use regulation and, possibly, rationing are to be used as management tools to protect the soil and vegetation resources, this relation must be well established.

Application

Applying impact research goes beyond the documentation of adverse soil and vegetation changes. Recreation managers must also consider how the public perceives the deterioration in terms of the total resource. As pointed out, impact may be concentrated at a relatively few locations scattered along the riverway. Visitors will probably continue to concentrate on these same areas for one reason or another and bypass the zones between. The bulk of the shoreline is seen from the river and never touched and, for many, the quality of the whole experience will remain high. For others the soil and vegetation deterioration will leave the greatest lasting impression. It is important that sociological considerations such as visitor perception be taken into account in assessing the importance of impact and apportioning the management dollar.

CONCLUSIONS

Concentrated recreational activity along our riverways, as in other natural outdoor settings, frequently produces adverse changes in the soil and vegetation. Considerable expertise is needed in the interpretation and application of impact research in a management situation. Both ecological and sociological considerations must be taken into account in evaluating the carrying capacity of a riverway for recreation.

ECONOMIC EVALUATION OF ALTERNATIVE USES OF RIVERS

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ABSTRACT.--Reviews the benefit-cost analysis decision criterion and the concept of opportunity cost. Outlines how to measure recreational benefits using the Hotelling-Clawson-Knetsch model. Discusses data and research needs for using benefit-cost analysis as a tool for making recreational river management decisions. Concludes that the ability to use benefit-cost analysis in river management exists and should be exercised.

The management of rivers and river segments requires allocative decisions regarding the uses to be made of them. Because these are primarily public decisions, benefit-cost analysis is the appropriate economic tool to guide the manager in making them. The purpose of this paper is to argue that benefit-cost analysis is also a useful tool for making river management decisions.

Conceptually, benefit-cost analysis is concerned primarily with economic efficiency and not with income distribution questions. As a social decision-making concept, then, it is incomplete and should be considered as just one element in the public decision-making process, albeit a very useful and important element.

Empirical benefit-cost analyses have been widely criticized. The primary criticisms have resulted from improper application of the economic model and incomplete accounting of costs and benefits. Improper application of the economic model can be avoided by education of analysts and by public vigilance to assure the economic validity of analyses. Incomplete accounting of costs and benefits may occur because of a desire to sell a project, negligence, or the inability to measure all costs and benefits in commensurable units.

Although benefit-cost analysis techniques may not be perfect, they are good and getting better. When Maurice Chevalier was asked how he viewed old age he replied: "Well, there is quite a lot wrong with it, but it isn't so bad when you consider the alternative".

The alternative to using benefit-cost analysis in public recreation planning is to continue as we have. That is, justifying decisions and budget requests on the grounds that recreation is "good" (and more is always better) and/or the rates of activity and area participation are increasing. Budget decision-makers will not settle for such justifications, nor should they. Benefit-cost analysis forces the definition of objectives and alternatives and the weighing of relative merit that budget decision-makers need and are looking for.

The inability to measure benefits is the most frequent criticism of benefit-cost analysis as a decision-making tool for efficiently allocating recreational resources. But our ability to make such measurements has increased substantially, and we should start making use of that increased ability. The measurement techniques, however, require data that are usually not available without undertaking a site specific study. The question is whether the decisions are important

enough to bear the expense of such studies. This symposium is evidence in support of the position that they are. Furthermore, the data requirements do not appear to be particularly burdensome when compared to existing and proposed studies of wild, scenic, and recreational rivers (Lime 1975a).

SOME ECONOMIC CONCEPTS

Benefit-cost analysis is a technique that can be used to aid resource allocation decision-making. Because the concern is with public decisions, the appropriate criterion for choosing among alternatives is the maximization of net social benefits (Herfindahl and Kneese 1974). The analysis, ignoring complicating factors, is one of objectively examining the costs and benefits of each alternative and choosing the alternative with the largest present net benefits. The decision criterion determines the appropriate measure of benefits and the concept of opportunity cost defines the costs that should be included.

Decision Criterion

The net benefits of an alternative will be maximized at the scale for which marginal benefits equal marginal costs. The demand function for the use of a natural environment expresses the marginal benefits of various amounts of use. The areas under the demand function for various quantities measure the total benefits of each quantity of use (fig. 1). Similarly, areas under the marginal cost curve measure the total costs of varying amounts of use (fig. 2). That level of use at which marginal benefits equal marginal costs will be the level that maximizes the difference between total benefits and total costs, net benefits (fig. 3). The maximum net benefits of each alternative are then compared and the alternative with the largest net benefits is chosen (Herfindahl and Kneese 1974).

The approach outlined is equivalent to maximizing the sum of all consumers' surpluses and all producers' surpluses (Kelso 1966). Further, the resulting allocation is equivalent to that which would result in a competitive market (Herfindahl and Kneese 1974).

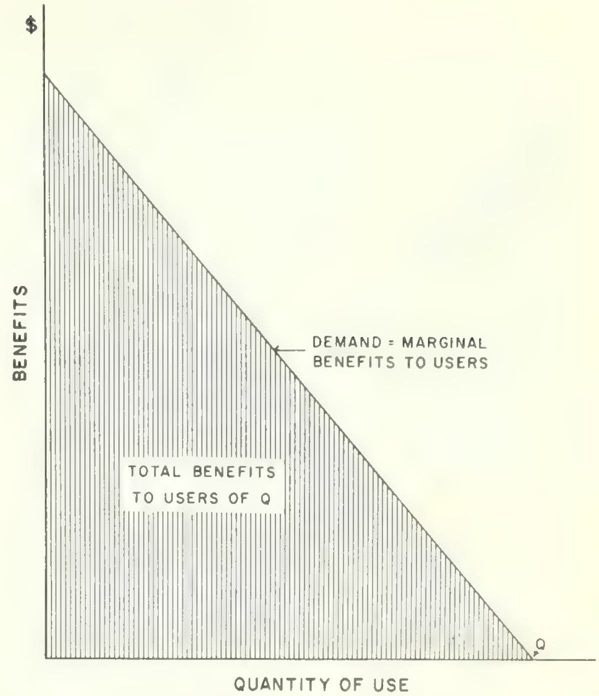

Figure 1.--*Demand function for use of a public natural environment.*

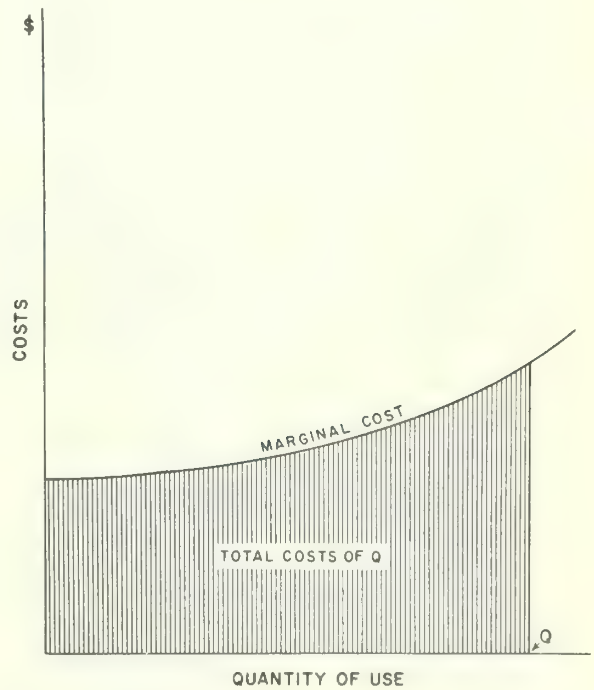

Figure 2.--*Marginal cost function for provision of use of a public natural environment.*

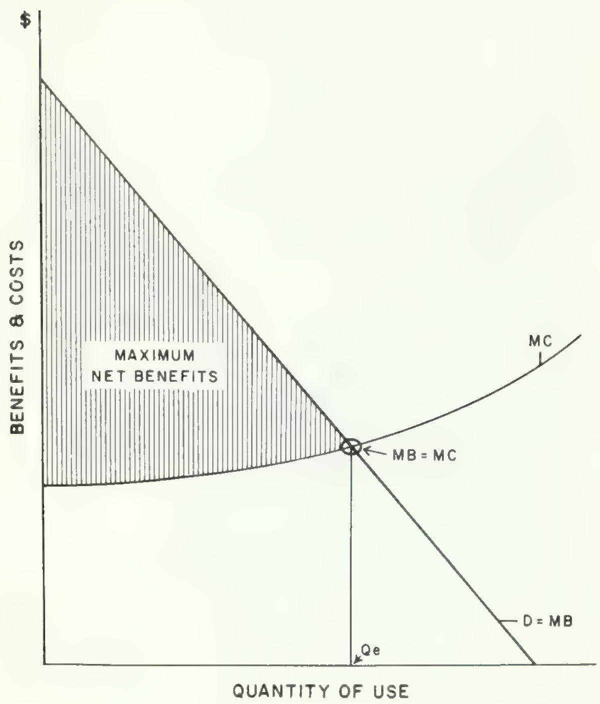

Figure 3.--*Level of use that maximizes net benefits.*

Costs and benefits occur over time and their magnitudes may vary at different times. The specific criterion of choice, then, is to choose that alternative that has the largest present net benefits. To calculate present net benefits, the flows of benefits and costs must be discounted to the present. The rate at which to discount them has been the subject of much discussion. Space does not allow a review of this discussion and the reader is referred to Krutilla and Fisher (1975).

Opportunity Cost

When one or more of the alternatives involves nonmarket benefits, costs may seem to be more easily measured than benefits. This mistaken impression arises from a limited concept of cost.

One of the basic concepts of the economic theory of production is that of opportunity cost. The opportunity cost of implementing an alternative is what must be given up because the alternative is implemented. For the marketed goods and services that may be required, money outlays are used as measures of their opportunity costs. The rationale is that these goods and services would be employed in other productive pursuits if they were not employed in the given alternative, and that their values, as reflected in their prices are derived from the values to society of these other pursuits.

The specific opportunity costs of an alternative depend on the nature of the situation. Herfindahl and Kneese (1974) pointed out: if you own an automobile and are considering using it or public transportation to make a trip, the relevant costs of using the automobile are the variable operating costs including gasoline, oil, tires, and wear and tear costs associated with the particular trip. These are not all of the costs of owning and operating the car, but are more than the out-of-pocket costs required for the trip.

On the other hand, if you do not own a car and are trying to decide between driving to work or taking a bus, then additional costs must be considered. In this situation you must also consider the costs associated with buying a car, such as annual depreciation, insurance, license, and interest on the investment. These costs are a part of the opportunity costs in this situation because they could be avoided by using the bus; whereas they cannot be avoided in the former situation in which the automobile was already owned.

But not all opportunity costs can be measured using market values. For example, building a dam on a river would mean that the benefits arising from primitive river travel would be given up. The loss of these benefits is an opportunity cost of the dam project and should be brought into the cost accounting. Furthermore, some project costs may be subsidized and the subsidies should be added into the costs.

So what we find is that benefits and costs are two sides of the same coin, but like the two sides of a coin, they are not identical. Hence, costs may be as difficult to measure as benefits.

BENEFIT MEASUREMENT

Over the past few years a bit of jargon has developed that categorizes the uses of natural environments as either commodity or amenity uses. A concern about this jargon is that the two words seem to convey a value judgment: commodity uses are more valuable than amenity uses because they are "productive" as compared to the "unproductive" amenity uses. But the terms are now imbedded in the literature, and we (or at least I) must learn to live with them.

Commodity Values

Commodity values are the benefits arising from the use of natural environments for mineral, timber, livestock, agricultural, water, and energy production. In older economic jargon these are producers' goods: inputs to subsequent production processes that eventually result in final consumer goods. The values of commodity uses derive from the values of the final consumer goods to which they contribute.

With the exception of timber, the real prices of these commodities have been decreasing over time (Potter and Christy 1962 , Barnett and Morse 1963). This means that the economic scarcity of these commodities has been decreasing relative to other goods and services. Technological advance has lowered production costs and increased substitution possibilities to the extent that their real prices have declined in the face of increasing demand for them.

Amenity Values

Amenity values arise from the direct uses of natural environments by final consumers, consumers' goods in the old jargon. These uses enter directly into the individual's consumption pattern with little or no intervening production technology. Therefore, technology has much less of an impact on the costs of or provision of substitutes for these uses as compared to commodity uses. User and option values are two types of amenity values.

Estimating User Values

User values are the benefits users of natural environments obtain through on-site activity of one sort or another. We have well-developed models for estimating the economic values of these benefits. The basic model is the travel cost model referred to as the Hotelling-Clawson-Knetsch (H-C-K) model (Clawson and Knetsch 1966). Two stages are involved in the estimation of value with the model. First, the demand function for the recreational experience in the given natural environment is estimated using travel costs as a price proxy. Then, in the second stage, a demand function for the natural environment is derived.

The demand function for the environment is the marginal benefit function of the users of the environment. The total benefits to them are estimated by finding the area under the demand function as was shown in figure 1. This quantity is referred to as total willingness-to-pay.

Value measured in this way is constrained by users' incomes because the users are considered as buyers rather than sellers. However, the effect of income on the demand for a good depends on the proportion of the consumer's budget spent on it. Typically, expenditures on an outdoor recreation activity at a specific site are a small proportion of a user's total budget so the income effect is small. If the users are considered as sellers, then a higher value is estimated because income is not a constraint. How much higher it is depends on the importance of income in the demand for the area. Therefore, the total willingness-to-pay value estimated using the H-C-K model is the lower bound value of an area in recreational use.

The H-C-K model has been extended and given more econometric sophistication to account for possible income effects, other demand shifting variables, and substitution effects (Smith 1975 , Gum and Martin 1975). More work needs to be done in refining the way in which substitution effects are handled. In one study, total or average expenditures on all other recreational experiences were used to account for substitution (Gum and Martin 1975). Recreational

experiences, however, combine activities and environments. The relations leading to the combinations are not well known. We need to know more about the characteristics of environments as they relate to the characteristics of activities in producing the characteristics of recreational experiences that form the basis for preferences and, hence, for substitution relations.

The H-C-K, or travel-cost model, uses observations of actual behavior to estimate the demand for the recreational experience. This is its greatest strength. With the improvements that have been made in its application, the model is extremely robust and can be used with confidence.

Appreciation of Benefits

The H-C-K model provides estimates of current annual benefits. There is a strong argument that these benefits will increase over time (Krutilla and Fisher 1975). The argument is based on two propositions. The first is that all natural environments, to some extent, are gifts of nature and not producible by man. Admittedly there is a continuum of environments from wilderness to KOA campgrounds over which the natural component varies in intensity. But to whatever extent an alternative use destroys whatever natural component an environment has, that component cannot be reproduced at a later date. Thus, natural environments are fixed in supply, and technology cannot ease this supply fixity through provision of substitute environments. On the other hand, continued technological advance will continue to relieve commodity supply restrictions by increasing materials substitution possibilities.

The second proposition is that demand for amenity uses of natural environments will increase over time as a result of increasing per capita demand and population growth. Technological advance contributes to increased per capita demand by increasing per capita real income. The result is a growing scarcity of the amenity services of natural environments relative to the commodity uses of such environments.

Evidence that the demand for and value of amenity services will grow over time is convincing, therefore, the appreciation of these benefits should be brought into benefit-cost analyses. Krutilla and Fisher (1975) present a simulation technique for estimating the rate of appreciation for linear demand functions. Based on the argument for benefit appreciation, the model simulates a situation in which the demand for amenity services shifts outward over time while supply remains fixed, imposing a carrying capacity constraint at some point.

The model breaks the shift in demand into a vertical component and a horizontal component. The vertical shift represents increasing willingness to pay for given quantities of the service and is assumed to be constant over time. The horizontal shift represents increasing quantities being demanded at given prices. The rate of horizontal shift is assumed to be constant to the time at which the capacity constraint is reached, after which it decreases to the rate of population growth. For many recreational activities, the rate of growth in participation has been greater than the population growth rate. This means per capita demand has been growing and more and more of the population is being exposed to these activities. Common sense tells us there is an upper bound to growth in participation, the rate of population growth.

The simulation model to estimate the rate of appreciation in recreational benefits is simple in that it abstracts greatly from the real world and, therefore, has a small number of parameters. These are the rate of vertical shift in demand, the rate of the horizontal shift, the year the area reaches capacity, the rate at which the horizontal shift decreases to the population growth rate after the year capacity is reached, and the year the horizontal growth rate equals the population growth rate. Data are not commonly available to estimate these parameters. Enough evidence exists, however, for choosing alternative values for the parameters so that the sensitivity of the results to the alternative values can be tested.

Option Values

Option values remain largely unmeasur

ble in economic terms. These values include the value to individuals of having the opportunity to visit an area in the future. The conclusion that this kind of option value is additional to total willingness-to-pay has been worked out, but no empirical method for estimating it has been developed (Cicchetti and Freeman 1971). Scientific values are also option values. These arise from our desires to pursue ecological research in undisturbed areas, preserve genetic information, and preserve potential sources of medicine. Also included among the option values are the vicarious benefits people gain from simply knowing such natural areas exist (Krutilla and Fisher 1975).

DATA AND RESEARCH NEEDS

To apply benefit-cost analysis, data are needed to estimate those benefits and costs we have the ability to measure. With regard to amenity uses of wild, scenic, and recreational rivers, these are the user benefits and some of the costs of providing the opportunities for recreational uses.

User Benefits

The H-C-K model is site specific and studies specific to individual rivers must be made to estimate user benefits. Although site specific, they need not be on-site studies.

The model uses travel costs as the price proxy in the estimation of the demand for the recreational experience. Thus, actual travel cost data or indirect data, from which travel costs may be calculated, must be obtained.

Some investigators have used trips and some have used visitor-days as the quantity variable. The variable that should be used in a particular situation depends on the amount of variation in trip lengths. When trips are used, it is useful to distinguish day trips, weekend outings, and vacations, estimating demand functions for each.

The observational unit is open to a choice among the individual, group, or household. The choice depends on the nature of the river and the activity.

In addition to the price and quantity variables, variables that may shift demand must be considered. These include income, travel time, socioeconomic, and substitution variables. When users have been aggregated by origins, multicollinearity between travel cost and travel time has resulted. The solution has been to drop travel time from the statistical demand functions, resulting in an incomplete specification of demand. The disaggregate approach, in which the individual user is taken as the analytical unit, avoids the multicollinearity problem and makes possible the inclusion of both travel costs and travel time in the estimated demand functions (Gum and Martin 1975).

The use of total or average expenditures on all other recreational experiences to account for substitution effects is not entirely satisfactory. More research is needed to identify the variables that express the nature of the substitution relations.

In most studies of the recreational users of an area, data on socioeconomic variables are collected. The additional variables required for benefit estimation may be income, travel cost, and substitution variables. Income and travel cost are straightforward variables and easily measured at little additional cost. The substitution variables eventually identified should also be of a straightforward nature.

The H-C-K model derives part of its strength from the fact it is based on observations of actual behavior. When considering potential uses of a river, however, there is no actual behavior to observe. One solution is to estimate benefits for similar rivers receiving such uses and apply them to the river being studied. This approach, called the representative site approach, was used in an Arizona study (Sublette and Martin 1975). Research of the kind being reported at this symposium by Chubb will provide a basis for identifying "similar" rivers.

Costs

Little attention has been paid to the costs of providing and maintaining recreational opportunities relative to

the attention given demand and value. Perhaps cost studies have been considered less challenging than demand studies.

Estimates of the costs of facility construction and maintenance and the costs of maintaining the natural and social components of recreational environments are needed. Facility cost estimates are most easily obtained. To estimate the costs of maintaining the natural and social components of these environments, however, is more difficult. The papers presented at this symposium by Settergren and by Heberlein relate to this issue. It certainly is not lacking in challenge. Nevertheless, once the alternative recreational experiences have been defined for a river, reasonable judgment estimates of such costs could be made.

SUMMARY

The state-of-the-knowledge regarding measurement of recreational user benefits is such that it is now possible to measure them with confidence. The total willingness-to-pay measure of value, the area under the demand curve for the environment, is the relevant measure given maximization of net social benefits as the decision criterion. This measure of value is constrained by income and is, therefore, a lower bound value.

Option values are still unmeasurable. They have been shown, however, to be additional to user benefits.

An argument that the demand for and value of amenity uses of natural environments will increase in the future is convincing. A simulation model for estimating the rate of appreciation in benefits has been developed. The model applies only to linear demand functions and requires parameter estimates not easily obtained.

On the cost side, facility constructi[illegible] and maintenance costs can be easily measured. Costs of maintaining the natura[illegible] and social components of natural environments are less easily measured. However, it should be possible to make reasonable judgment estimates of these costs given definition of the potential recreational experiences to be considered for a river.

While all of the problems of cost and benefit measurement have not been solved, the state-of-the-knowledge has reached a level at which it is possible to begin using benefit-cost analysis as a decision-making tool in the management of wild, scenic, and recreational rivers.

DENSITY, CROWDING, AND SATISFACTION: SOCIOLOGICAL STUDIES FOR DETERMINING CARRYING CAPACITIES

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ABSTRACT.--Four types of carrying capacity are identified: physical, ecological, facilities, and social. The importance of both levels of technology and value judgments are noted for determining any of these capacities. The satisfaction model based on an explicit or implicit adoption of ecomonic theory by both researchers and managers for determining social carrying capacity is found wanting and an alternative model based on a determination of social norms is proposed. This model is discussed both in terms of recent social psychological studies of crowding as well as prior assessments of recreation carrying capacity. Finally, some practical suggestions for adopting this model are noted.

The recreation carrying capacity of wilderness has received the attention of social scientists for over a decade, beginning perhaps with the thoughtful analysis by Wagar published in 1964 and complemented by the pioneering empirical work of Lucas (1964c) in the Quetico-Superior. Since then the work has been advanced by continued studies in the Quetico by Lime (1970) and in other areas by Stankey (1973). The complexity of carrying capacity determination has been spelled out and progress has been made at sorting out the components of capacity (Lime and Stankey 1971 , Frissel and Stankey 1972 , and Bury 1976). In doing so, researchers are telling managers that no single number exists but rather combinations of factors including management objectives, the physical and biological nature of the resource, the preferences and tolerances of the users must be considered together in selecting a capacity for a given area. Carrying capacity is thus a dynamic concept (Stankey 1974) and is difficult to pin down to a specific number.

A major stumbling block to these efforts to establish a carrying capacity is that they have been based on an economic model. This approach is either explicit as seen in the work of Alldredge (1972), Fisher and Krutilla (1972), Cicchetti and Smith (1973) or implicit in the Forest Service research (Stankey 1971 , Lime and Stankey 1971). No one can argue with the elegance and internal consistency of these models. However, any model must simplify the world, and in doing so, some untested assumptions must be made. Unfortunately, the primary simplifying assumption of the economic model does not square well with a social-psychological model of human behavior. Data necessary to test this assumption come from a recently completed study of crowding on the Colorado River in the Grand Canyon (Shelby 1976). Further, data I have collected on the Bois Brule River in Wisconsin essentially replicate and consequently extend the findings from the canyon to other rivers. In addition to these new data, social-psychological research has begun to extend biological work on crowding to humans. The thrust of this work complements sociological research on river visitors, and these two bodies of literature will be discussed in this paper as a means of both giving a sociological direction to carrying capacity research and integrating prior work on crowding and carrying capacity.

PHYSICAL CAPACITY AND ECOLOGICAL CAPACITY

Theorists have usually discussed carrying capacity under two rubrics: those dealing with natural features and those dealing with human components (e.g., Lucas and Stankey 1973 , Lime and Stankey 1971 , Bury 1976 , Fisher and Krutilla 1972). I have found it useful to further differentiate these into four related categories: physical, ecological, facilities, and social, which may be used in roughly a descending order to establish capacities.

The upper limit of capacity is the amount of physical space available for humans. In the Grand Canyon, this might be the number of spaces available along the Colorado River for visitors to camp and sleep in the evenings. Allocating all of the available beach spaces into cooking and sleeping areas large enough to accommodate an adult human would yield a carrying capacity far in excess of current visitor limits.

A second and the most widely recognized and discussed capacity has to do with human impact on the ecosystem. Clearly if the physical capacity of the Canyon or any river bank or lake shore were reached every night of the season, dramatic impacts on animal and plant life would result. Ecological capacity is difficult to establish, for *any human use will have an impact.* The critical question is how much impact is tolerable.

Value Judgments Necessary

To establish a carrying capacity once impacts have been measured someone must say, "This much is enough". This means that selecting a carrying capacity implies some kind of value judgment, even in the case of physical capacity. Under one set of values, physical capacity in the canyon is reached when there is one party on the beach. Under another set, when there is one person for every 3-by-7-foot sleeping location in the canyon. The question of the appropriate mix of expert, scientific, and public judgment is at the heart of carrying capacity controversies.

Managers would like to think carrying capacity can be determined solely by scientific and technical information, and thus avoid the apparent arbitrariness of value judgments. The only time that such data alone appear to make carrying capacities determinations, is when the value premise is widely shared.

For decades biological studies have been used to establish carrying capacities, particularly for deer, elk, and livestock. These studies have helped managers make decisions because the value premise is explicit and widely shared (production should be at a maximum without impairing the range). When, however, there is wide disagreement about what is valued, no decision can be reached. When ranchers cry out for zero predators and environmentalists demand wolves and coyotes be preserved, biological studies cannot in themselves establish a carrying capacity.

Lucas and Stankey (1974) note that the concept of carrying capacity may be useful for range management but is ill-suited for recreation management. (They go on to use it, however, because of its wide circulation). Recreation researchers have recognized the importance of shared values in their selection of sites for the study of carrying capability. Such studies have tended to focus on wilderness recreation rather than crowding in campgrounds, zoos, or picnic areas because there tends to be a greater value consensus about the nature of a quality wilderness experience. Of course, wilderness recreation should be the most sensitive to minor changes in visitor density.

Level of Technology Necessary

Just as a value premise is necessary to establish carrying capacity, any carrying capacity must be based on a specific level of technology. If visitors to the Grand Canyon were to sleep in boats as well as on beaches, the physical capacity of the canyon could be increased. The introduction of new technologies including "porta potties" in the Grand Canyon have reduced human impact on the biology of the inner canyon, and consequently have raised ecology capacity.

The addition of technology into a given recreation activity is a two-edged sword. While on the one hand it may be used to reduce impact and increase carrying capacity, in the case of river running itself, the introduction of rubber rafts and

ubes has led to crowding problems on rivers ll over the nation. On the Colorado iver, the introduction of new technology Glen Canyon Dam and the regulation of ater levels on the Grand Canyon) has ramatically affected use in the last ecade.

FACILITIES CAPACITY

To handle visitors physical and organ- zational facilities, such as parking lots r boat ramps, are needed. When parking ots are full or boat ramps covered with afts loading, the carrying capacity of he facilities has been reached. In the ong run, facilities capacity is not a erious problem, although it may be fixed or a single season. While physical or cological capacity can be manipulated by he introduction of new technologies, acilities capacity can be greatly en- arged by the application of dollars. arking lots may be built, boat ramps ex- anded, and more personnel hired, for where here is demand, the income needed to ex- and facilities capacity is at least otentially available.

SOCIAL CARRYING CAPACITY

Throughout the literature is the otion that there is some visitor density hat reduces the quality of the recreation xperience (Lime and Stankey 1971 , rissel and Stankey 1972 , Stankey 1972 , ucas and Stankey 1974 , Fisher and Krutilla 972 , Stankey 1974 , Bury 1976). We ight call this social carrying capacity. ow many visitors can be put into an area efore the quality of their experience s significantly reduced? Social carrying apacity also requires a value judgment. ow much human interaction is too much? hen is the experience significantly educed? However, the problem is even more ifficult in the case of social carrying apacity, because there is even less value onsensus about the nature of a recreational xperience than there is about a preferred cosystem. Moreover, recreation research s far behind the theoretical development f the biological sciences. Consequently, mong scientists there is little shared greement about what variables to measure nd how to measure them. Social scientists re hard pressed to gather the appropriate ata to determine the impact of humans on he recreational experience of others.

The utility of these four kinds of carrying capacity may be illustrated for river recreation in the Grand Canyon. Currently in the Grand Canyon, use is nowhere near *physical capacity*. *Ecological capacity*, with the introduction of porta potties (although further study is needed), is probably far above current use limits. In any case, even extreme human recreation impact is probably trivial compared with the dramatic impact of the Glenn Canyon Dam on the river ecosystem. *Facilities capacity* is alleged to be 150 persons per day at the Lee's Ferry put-in point. However, Park Service records show this was exceeded 20 days out of the 1974 season (Shelby and Nielsen 1975a). In any case, more staff, parking and loading zones could easily alleviate that problem.

The real limiting factor in the Grand Canyon may be *social carrying capacity* where the number of people influences the nature of the experience. I suspect this is true for much back country recreation. On the other hand, in certain areas, ecological limits will be the first to be exceeded. Facilities limits will in other cases be reached before other capacities have been exceeded. Physical carrying capacity is unlikely to be reached in any area. However, it serves as a starting point from which the issue of carrying capacity may be considered.

Although managers are implicitly concerned about social carrying capacity and providing a visitor with a particular kind of recreational experience, they are uncomfortable at limiting use on the basis of such criteria. Some of this reluctance is due to the diversity of opinion as to what a high quality recreational experience is. Because there is more likely to be consensus about biological impact or facilities capacity, managers may select such limits even though they are actually managing for a particular kind of recreation experience. Managers seem more comfortable saying, "The parking lot isn't big enough so you can't come in," rather than saying "You can't come in because too many people will reduce the quality of the experience for others." Facilities carrying capacity may be a useful way to limit numbers once ecological or human carrying capacity has been reached. However, as a

fixed limit in itself in the face of rising demand, it is not generally defensible.

Resource managers, as Hendee and Stankey (1973) have pointed out, by reason of training and personal values, tend to over-emphasize biological capacity. Numbers are often limited on the basis of demonstrable but trivial biological impact. Or numbers are allowed to exceed the point where the important components of the recreation experience are lost (e.g., solitude) because no biological impact can be documented. There are no doubt biological limits and carrying capacities, but these should not be used to avoid hard decisions about another sort of capacity.

The subterfuge of using facilities or biological capacity, although convenient for the manager, may be an inefficient and ineffective means of both establishing or regulating social carrying capacity. However, in the absence of more adequate standards for social carrying capacity, the manager can hardly be faulted for using other criteria. The theoretical basis for establishing social carrying capacity is weak, and current methodologies illsuited for making such a determination. The remainder of this paper is devoted explicitly to that problem.

SATISFACTION AS THE BASIS OF SOCIAL CARRYING CAPACITY

Social carrying capacity has been defined largely in terms of visitor satisfaction. Bury (1976) states, "The objective of recreation management is to maximize user satisfaction within the specific constraints of budget or physical resources or agency policy". Lucas and Stankey (1973) indicate within constraints "...we assume the goal of recreation carrying capacity is to maximize user satisfaction". Lime and Stankey (1971) define carrying capacity in terms of that level which can be supported without "...excessive damage to either the environment or the experience of the visitor". The emphasis on satisfaction is always couched in terms of constraints (such as management objectives). I will try to show that it is those constraints, rather than satisfaction, which are really the important parameters is establishing social carrying capacity.

This notion of satisfaction is also important in the perception of managers. Within ecological and budget constraints, managers say they wish to provide for as many satisfied visitors as possible. Dissatisfied visitors are a problem for managers; so is turning away other visito who might be satisfied with the experienc Managers generally view their role, after protecting the resource, as providing an experience that will please visitors.

Theoretical Basis of the Satisfaction Model

While the satisfaction model is at the basis of theorizing about carrying capacity and is also implicit in management, it has reached its full flower unde an economic analysis of carrying capacity Alldredge (1972) spelled out the basics of the model in simple terms easily grasp by managers and sociologists alike. The Resources for the Future Investigators (Cicchetti and Smith 1973 , and Fisher and Krutilla 1972) stated it in quantita and operational terms.

Briefly stated, when a person enters a wilderness area alone, he has some amou of satisfaction (called enjoyills, by Alldredge, and operationalized by Cicchet and Smith and Fisher and Krutilla as willingness to pay). This is alleged to decrease for the first individual as subsequent visitors enter the area. However because it does not immediately drop to zero, aggregate satisfaction across visitors continues to increase. When the amount of satisfaction of the nth visitor does not equal the drop in satisfaction o the remaining visitors and the aggregate satisfaction begins to decline, social carrying capacity is reached.

This is a conceptually consistent notion of social carrying capacity that fits well with a management objective of what might be called satisfaction management, and generally follows Stankey's analysis of carrying capacity (Fisher an Krutilla 1972). Moreover, it can readil lead to selection of a number at least in the theoretical descriptions of the model

Problems With the Satisfaction Model

The satisfaction model so oversimplifies the nature of a complex, real-world

rocess to achieve a social carrying capacity estimate that it loses touch with he process itself. Two studies (Stankey 973 , and Cicchetti and Smith 1973) ave shown that wilderness visitors will how lower levels of satisfaction or a educed willingness to pay when asked their eaction to *hypothetical* encounters in ilderness areas. This supports the basic remise of the satisfaction model, "...the atisfaction or ability gained from the ilderness experience tends to be inversely elated to the number of parties he meets n a wilderness outing" (Fisher and rutilla 1972).

However, until recently no one ever ooked to see if this premise held in an ctual recreational setting. *Are wilderess visitors who encounter many parties eally less satisfied than those who see ew?* For two summers, observers who ounted the number of encounters, were laced in boats on the Colorado River in he Grand Canyon. Visitor contact at ttraction sites, the length of contact n the river, and the number of people een in those encounters were also noted. hese data were then related to satisfacion scores of visitors on the trips.

During the 1974 season, 213 visitors n 11 trips filled out questionnaires Shelby and Nielsen 1975) and *the corelations between satsifaction and the ensity measures were not significantly fferent than zero.* In 1975, the study as replicated with a representative sample trips (Shelby 1976). Here, 1,009 isitors completed questionnaires (a 96 rcent response rate) on 46 trips. Even th this large sample, only the correlation tween length of time in sight of people the river and satisfaction was statiscally different from zero (r=0.10). Hower, this correlation accounts for only percent of the variation in satisfaction, rdly enough to be an important issue in tisfaction management. The other varbles, such as number of contacts and mber of people seen, were not related to tisfaction.

It may be argued that the Grand Canyon such a unique resource that it overwers any effect of density on satisfacon. However, I am currently analyzing ta that appear to support the Grand nyon findings.

During August 1975, nearly 3,000 canoeists, tubers, and fishermen on the Brule River in Wisconsin were interviewed. The correlation between daily use as measured by electric eye counts up river and satisfaction was 0.009 (NS) indicating again that visitor number plays no role in the overall satisfaction of the visitors present on this recreational river. These studies should be replicated in other wilderness areas, but cast substantial doubt on the basic premise of the satisfaction model.

Why Doesn't Satisfaction Relate to Density?

Satisfaction is a complex concept and there are likely to be many things other than the number of encounters, or length of encounters that affect satisfaction. Freedman (1975) argues in his discussion of density-intensity theory that in many circumstances people are simply not attending to density, and it simply may not be a factor in their experience. For example, while those few who experienced the Grand Canyon before 1960 may be appalled by 1970 use levels and contact their congressmen, most visitors may not notice.

Grand Canyon visitors are not only very satisfied but 31 percent of the variance in satisfaction is explained by the social aspects of the trip (e.g., subjective quality of group experience), personal benefits, the wilderness character of the trip (e.g., being in wilderness an important reason for the trip) and weather (Shelby 1976). Perceived crowding accounted for only an additional 2.5 percent of the variance and 6 additional density variables added another 2.5 percent, bringing the total explained variance in satisfaction to 36 percent. Wagar (1964) anticipates these findings in his discussion of the multiple satisfactions that may be derived from a particular recreation experience.

It may be argued that density in the Grand Canyon was simply not high enough to show any effect on satisfaction, that surely as physical capacity is approached satisfaction must go down. Shelby and I, responding to a note by Greist (1976), don't believe this would inevitably be the case.

Users choose activities that are in

accord with their own idea of a "good time." Those who don't like the anticipated crowds in Grand Canyon will (as some have already done) not return but move on to less crowded areas, thus being "displaced" by those more tolerant to higher densities. Crowding norms, then, change due to alterations in group composition. The result is that aggregate satisfaction continues to climb with increasing use, and carrying capacity (the point at which satisfaction declines) is never reached. This may be especially likely in the Grand Canyon where 90 percent of the visitors are making their first (and for most, only) trip. Most of these visitors say that they had *no* expectations about how many other groups they would meet on the river (Shelby 1976). Individuals are susceptible to viewing what they see as appropriate where they have no prior expectations. This would tend to mitigate against any effects of density increases.

Further, increasing densities may cause a change in the definition of the experience. Increased use alters the character of the experience form, for example "zero contact wilderness", to "moderate contact semi-wilderness". Use levels that began to approach physical capacity in the Grand Canyon would move to the "excursion" experience, where one expects to see others viewing the same resource. As this happens, people probably change their normative definition of appropriate contact levels. Changes in the experience, then, cause individual normative changes, and satisfaction remains high. This subtle "product shift" would again mean that aggregate satisfaction continues to climb as use increases.[1]

A management policy aimed at maximizing aggregate satisfaction leads to some interesting possibilities. For example, a Grand Canyon Parkway along the Colorado River would certainly increase the number of satisfied Canyon visitors. Dissatisfied seekers of wilderness might go elsewhere. The influx of people more tolerant of crowding would cause contact norms to change, and the new product (the Grand Canyon by automobile) would be defined in terms of higher contact rates.

[1]*Personal communication with Stankey, 1976.*

Satisfaction Alone is not Suitable Criterion for Management

Neither the USDA Forest Service researchers nor the economists have proposed satisfaction as the *sole* criterion for establishing carrying capacities. Lucas and Stankey (1974), Lime and Stankey (1971), and Frissel and Stankey (1972) have carefully limited the notion of carrying capacity to those numbers that could be satisfied within management objectives. The economists have likewise discussed satisfaction within the context of a certain product--"a wilderness experience" (Fisher and Krutilla 1972). Hence, satisfaction itself is not as suitable criterion for defining these limits. *It is likely that for a wilderness experience, the number of visitors may reach the point where the experience is no longer provided even though there may not be a noticeable reduction in satisfaction of the visitors present.* Consequently, if certain types of recreational experiences are to be provided in the face of increased user demand, *some criterion other than satisfaction must be used to establish social carrying capacity.* The remainder of this paper is devoted to some notions which may help select these capacities. The first step in developing an operational approach to establishing carrying capacity is to focus our discussion on the concept of crowding.

SOCIAL PSYCHOLOGICAL MODELS

Since 1970, social psychologists have begun to build on the work of sociologists (e.g., Winsborough 1965 , Galle *et al.* 1972) and biologists (e.g., Christian *et al.* 1960) regarding crowding. The notion of crowding is really central to the determination of social carrying capacity. Social carrying capacity for an activity has been reached when the participants regard the setting as crowded. Crowding is more than just the number of people present. Most theorists (Altman 1975 , Stokols 1972a and 1972b, Desor 1972 , Lawrence 1974 , Rappaport 1975) distinguish between density and crowding. Density refers to the number of individuals in a particular setting and their distribution. Crowding is the negative evaluation of a density that exceeds a certain point. In our focus on the negative aspects of excessive density, it is important

to remember that density may be too low as well as too high. Frequently mentioned examples include too few people at a football game or a cocktail party. The language lacks a term such as crowding to describe the absence of sufficient numbers, although terms such as over and under manning (Wicker 1973) may serve in the technical literature.

The Return Potential Model

The distinction between density and crowding implies that the appropriate level of human density in a particular situation is essentially a normative concept. There may be too few, just right, or too many. Jackson (1965) proposed a model that may be helpful for considering carrying capacity. This model is called a "return potential curve" and works like this:

Individuals are asked how they would feel about seeing 1, 2, 3, 4...n other people in a particular setting. By plotting the mean responses on a graph where the favorableness or unfavorableness of the evaluation is plotted on the x axis and numbers are plotted on the y axis, one establishes a return potential curve.

Figure 1 shows three hypothetical return potential curves for three different activities: a wilderness experience, a cocktail party in a small room, and a city sidewalk. For a wilderness experience, reaction to numbers is most favorable at zero and crosses into the negative values at four, when respondents began to evaluate density unfavorably. The range of appropriate numbers is narrow, ranging from zero to four. A cocktail party, on the other hand, has two regions of rejection, both when there are too few participants, and when finally there become too many in the room to converse, obtain drinks, etc. The latitude of acceptance is broader for a cocktail party than for a

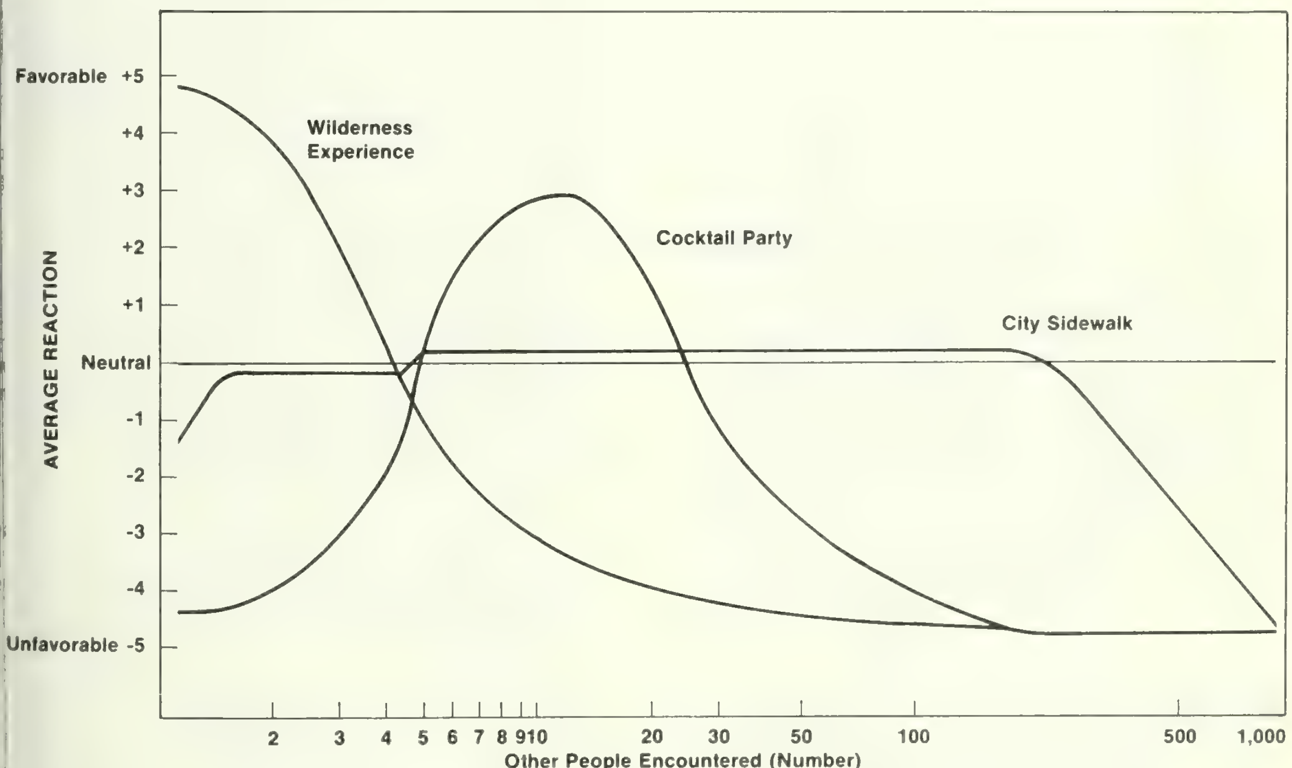

Figure 1.--*Return potential curves for three activities.*

wilderness experience, ranging from 5 to 25. The latitude of acceptance for a city sidewalk is broader still, ranging from 11 to 400, but drops off substantially when one can no longer negotiate from the sidewalk. Such return potential curves show the strength of the social norm by the height of the modal point: higher the mode, the stronger the norm. The norms about contacts in wilderness areas are more strongly crystalized than the norm for cocktail party interaction. Sidewalk contacts are generally unguided by norms except for empty or impassable sidewalks.

These return potential curves illustrate the relation between density and crowding. Seven people (a constant density level) is a crowd in wilderness areas, but not a crowd at a cocktail party or on a stroll down the sidewalk. When the density level exceeds this range of tolerable contact, the effects of crowding should be observable both psychologically and behaviorally.

Normative Explanations in Crowding Research

Recent social psychological literature illustrates some of the points raised in this discussion. Cohen *et al.* (1975) showed that college students are influenced by both the setting and the activity in the number of individuals they would place in a room "...until they felt that the addition of one more figure would create a crowded situation". More people were acceptable in the same size room for recreation (a party or social hour) than for work (working on a group project or a business meeting). Desor (1972) corroborated this. These studies suggest that different activities have different return potential curves.

Normative Explanations Help Reconcile Inconsistent Findings in the Crowding Studies

It has been widely assumed that increase in density in the social world such as cities, apartments, and urban life in general would cause negative pathological effects (Freedman 1975). However, large scale studies investigating this phenomenon have shown either no such effect or no effect beyond social class differences (e.g., Winsborough 1965 , Mitchell 1971 , Freedman 1975).

This lack of density impact in the sociological studies has been largely replicated in the early social psychologi laboratory studies. In these studies, placing more and more college students on chairs in a room had no effect on performance of individual mental tests (Freedm *et al.* 1971). Freedman *et al.* (1972) also found that room size had no effect o the aggressiveness of decisions made by mock juries.

However, recent studies have begun t show density effects on task performance. Paulus *et al.* (1976) argue that the lac of crowding effects in prior work may hav been due to the insensitivity of the task used by Freedman and his associates. Usi a maze task, they found that more errors were made under crowded conditions. One interpretation of this is that the two activities have different return potentia curves. Density may not have reached the subjective crowding level sufficient to influence performance in Freedman's experiments because people were sitting on chairs in a room as they filled out paper and pencil tests. No matter how close th chairs, the normative character of the setting had not been changed. However, just as the student approaching a pin bal machine says "stand back", indicating a preference for a given amount of space, performance on the maze task could have been influenced by the close proximity of others doing the same task. In short, there are probably different return poten tial curves for test taking and game playing (or maze running in this case). The density level in Freedman's work did not violate the test taking norm, but the density level did violate the game playin norm in the work by Paulus and his associates.

Findings presented by Worchel and Teddlie (1976) are also consistent with the normative interpretation. They had college students work on two group projec (as opposed to the individual tasks used by Freedman and his associates) at variou densities. Crowding distorted time perce tion, but had no effect on task performar However, interaction density was also varied. When chairs were close together (touching in a circle), performance went down and subjects became more punitive in their group reaction to a hypothetical juvenile delinquent. Subjects in the hig

interactional density conditions also attributed more aggressiveness and nervousness to the group members. *It appears that there is a different norm for group communication.* Here, when chairs touch, people both feel crowded and show a performance and psychological reaction, while for individual cognitive tasks, touching chairs does not violate the norm.

NORMATIVE EXPLANATIONS IN CARRYING CAPACITY RESEARCH

In the struggle to solve carrying capacity problems, recreation researchers have used normative kinds of approaches in three ways. First, Hendee and his associates (1968) developed a measure of wilderness purism that has been refined and used by other investigators (Heberlein 1973 , Stankey 1972 , and 1973 , Shelby 1976) to identify a particular group of wilderness visitors who are supposed to have more sensitive responses to a wilderness experience. Restated in terms of norms, this group is seen as having different expectations and norms about appropriate behavior in wilderness areas than the typical visitor. Hendee *et al.* (1968) and Stankey (1972) argued that wilderness management should be consistent with these norms, because there are fewer substitutes available for this group than for the general visitor.

Second, Stankey (1973) has gone beyond this approach to develop preference curves, much like the return potential curves described above for the number of contacts and the type of party encountered. His curves are similar to those presented in the hypothetical figure in this paper. They specify essentially the range of latitude for contacts before a wilderness type experience would be lost. The curves drop sharply from one to three and level off after five. Such graphs tell managers that one to five contacts are enough. As expected from a normative perspective, wilderness purists show steeper curves than the general visitor.

Carrying capacity research and management have been influenced by a normative perspective in a third way. It has been widely demonstrated that the phenomenon of asymetrical antipathy exists in wilderness type recreation (Lucas 1964a, Stankey 1973 , Lucas and Stankey 1973). For example, the paddling canoeist tends to dislike the motor boater, but not the other way around. This appears to also hold for hikers and horse parties, cross country skiers and snowmobilers, and rowers and motor boaters in the Grand Canyon as well. The groups essentially hold different norms about what is an appropriate behavior in a wilderness area. The motor boater, horse packer, snowmobiler, appear to believe that a wider variety of behaviors are appropriate than do the canoeists, hikers, and skiers. Management, which tries to isolate the uses from each other, is being implicitly influenced by a normative model.

Problems in Application

There are at least three difficulties in using norms for establishing carrying capacities. One just alluded to is that various users may have different norms. For example, appropriate density is different for tubing than for canoeing and fishing. This problem may be avoided by zoning activities to different segments of a river or to different times on the same river segment.

A second and more difficult problem is that visitors may have no expectations or no norms that apply to new situations and consequently cannot evaluate crowding consistently (Shelby 1976).

An allied problem involves norm formulation itself. How does one develop norms or expectations about appropriate numbers for a particular setting and recreational activity? Generally, it is done on the basis of past experience. Consequently, even though the character of an experience may gradually deteriorate as new users are introduced into the activity and density increases, each new generation may become more tolerant of increasing numbers. Today a wilderness experience may come complete with wide, groomed trails and signs at junctions indicating mileage to the next point of interest--a far cry from a frontiersman's notion of wilderness.

CONCLUSIONS--HOW TO ESTABLISH SOCIAL CARRYING CAPACITY

It is not possible, on the basis of satisfaction alone, to establish a social carrying capacity. Repeated surveys of

visitors will continue to show high satisfaction levels even as the character of the experience changes. How then does a manager establish a carrying capacity?

Specific Management Objectives

Although it is agreed that carrying capacity can only be established within the context of management objectives (Wagar 1964 , Lime and Stankey 1971 , Lucas and Stankey 1973 , Heberlein and Shelby 1976), no one talks much about these objectives. To be effective, the objectives must define specifically what type of recreational experience is to be provided, e.g., a chance to see a particular site, to have a particular experience. Where there are more than one of these (and there usually will be), they should be ranked. Management objectives should also indicate for whom the experience is to be provided. Management objectives such as "protect the resource", and "provide satisfying experiences" are not specific enough to help determine carrying capacity.

Visitor Assessment

The next step is to determine what actually happens. How often are people in contact with each other? Where do they camp and stop? What adjustments are made by visitors to reduce crowding? Although most such data are behavioral, study of perceived crowding preferences may be a useful part of visitor assessment. This is routinely done as in the case of ecological impact, but is rarely done for social impact.

Normative Assessment

Having specific management objectives and knowledge of the social impact, the manager is in a position to assess norms to determine if contact is excessive. Essentially this process would be to generate the return potential curves such as those described in figure 1. In practice, it need not be so formal. By going to various groups and asking if the contacts are too few or too many, the manager can get a rough idea of the described curves. It is *very* important, however, that a variety of potential users and nonusers (such as managers) be consulted. It is also necessary that this input be presented according to the various groups rather than just adding them all together in a "vote". This will give the manager a sense of the variety of norms that exist for visitor density in a particular setting, for a particular activity.

Determining social carrying capacity will never be an easy decision, yet if it is based on such information, it will be more defensible than the kind of arbitrary number picking currently practiced.

METHODS FOR COUNTING RIVER RECREATION USERS

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ABSTRACT.--Counting and classifying recreation users on the nation's rivers is a new technical endeavor. Procedures for documenting river use are reviewed and the merits and limitations of various approaches are discussed.

The commitment of public agencies to intensive management of rivers for recreation creates the need for information in a broad range of disciplines. One of the most basic kinds of information sought by managers is an account of the varied uses occurring on the Nation's rivers. Use statistics are often prerequisite to a meaningful interpretation of other kinds of data. Conclusions about resource impacts and user perceptions, for example, can be defined more precisely when the character and intensity of use occurring on a river is known. It may also be desirable to monitor river recreation to assess the effectiveness of management actions.

In many instances recreation managers may only be concerned with documenting the volume, distribution, and kinds of uses occurring on a river. More demanding situations may require information addressing such things as separation of river traffic in both space and time, access use, origin-destination patterns, watercraft ownership, etc.

River recreation is usually not distributed uniformly either in time or space. Peak hours and days typically characterize the use regimen, especially in situations where day-use activities such as swimming predominate. Some types of recreation, such as fishing, tend to be concentrated at selected locations, while other activities, such as canoeing, may be highly mobile and occur over extended portions of a river corridor. River traffic may also be two-way and comprise many different classes of watercraft and user groups.

For these reasons it should be recognized that a *precise* measure of all types of river recreation may be impractical to attempt on many rivers. If serious impediments to sampling exist, managers may have to limit their focus to the most important recreation uses. This does not necessarily mean that only the dominant or most visible activities should be measured. River uses such as night fishing could be minor occurrences yet still be important from a management viewpoint.

This paper examines methods and procedures currently used for gathering and interpreting river-use data. Because the focus is on the quantitative dimension of river recreation, methods used to obtain sociological and demographic data are considered only if a particular method can be used for both purposes.

Overlaps and ambiguities exist in some of the terminology used to describe use-estimation procedures. The intent here is to *characterize* selected methods, not to rigidly *categorize* them.

The task of securing quantitative river-use information is examined in the following sections from two perspectives: (1) the basic approach or rationale adopted for compiling and interpreting the data, and (2) specific techniques that may be applied to acquire the data.

APPROACHES TO MEASURING RIVER-USE

Total Accounting Approach

Under ideal circumstances it is possible to account for all use occurring on a river. Relatively simple situations having limited access, uncomplicated jurisdictions, and essentially homogeneous uses lend themselves best to this approach.

A total accounting of river use is feasible when the opportunity exists for use statistics to be generated as the by-product of an existing program involving use allocation. Otherwise there must be strong justification for the effort and expense that will be required to obtain complete use data. Often it is unnecessary to attempt a complete inventory of all uses on recreation sites (James 1971).

On rivers where managing agencies have instituted trip permit or floater registration systems, excellent opportunities exist for a total accounting of use. An advantage of this arrangement is that demographic data can be obtained simultaneously and participation in activities associated with the principle uses can often be measured. The gathering of river-use statistics by permit systems is usually practical only where formal controls have been imposed for other administrative purposes. The acquisition of use data is in itself a weak justification for regulatory measures unless the data is critically needed for management decision making.

Continuous counts can also be made of river activities, principally floater type uses, by electronic and optical recording devices. Opportunities to obtain complete use data over extended stretches of river may be limited, however, by cost and logistic constraints, and by the complexity of use patterns. It may be necessary, for example, to obtain supplemental origin-destination data to resolve the problem of duplicate counts of watercraft made by recording devices at several locations on large rivers.

Use Estimation

Sampling methods can often provide acceptably accurate estimates of outdoor recreation uses at a reasonable cost. On rivers, as anywhere else, the development of a valid sampling design requires some prior familiarity with prevailing use patterns. Statistical estimates derived from sample observations can only be as valid as the rationale and assumptions that underlie the sampling procedures. Especially important is the need to identify important variables in use patterns and to stratify the sampling design to assure that these factors are accommodated in the estimate.

Direct Sampling

Direct sampling is taken here to mean the recording of selected objects or events at predetermined intervals to establish a basis for estimating the total number of occurrences in a given area during a specified period of time. The essential feature of this approach is that the object or activity being measured is *directly* recorded during the sampling procedure. Passive enumeration techniques, including human observation and remote sensing technologies, are applicable to this approach.

The chief shortcoming of direct sampling is that only the *number* of users (or vessels) is estimated. Supplemental information is required to produce a quantitative measure of many related parameters important to river managers. To illustrate, consider the task of estimating raft use on a river. Periodic sample counts of rafts can produce a reliable estimate of the number of rafts operating on a river during a given period. Perhaps this information is sufficient to meet the needs of management. However, if the concern is to document raft use in terms of user days, it becomes necessary to obtain supplemental data providing a measure of average trip duration and the usual number of occupants per raft. If additional information is desired, a compound sampling approach is necessary.

Compound Sampling

Compound sampling involves the coordinated use of two or more sampling techniques. One application requires the establishment of a statistical correlation between some *indirect* use parameter,

vhich can be easily measured, and the :ecreation activity of concern. After a proper calibration is made, measurement of the indicator can be used as a basis for projecting an estimate of the recre-ation activity being studied. The widely acclaimed double sampling method by James and Ripley (1963a), and used extensively by the USDA Forest Service for estimating recreation uses on forest lands, is per-haps the best known application of this approach. Axle counts, parking lot attendance, metering of utilities, and other indicators have been used as a basis for the procedure (Elsner 1970, James 1970, James and Tyre 1967). To apply the method it is necessary to establish a strong cor-relation between the parameter being measured and the number of participants in the activity being studied. Unless this is done, a reliable estimate is not possible. James *et al.* (1971a) noted, for example, that counts of parked cars were not a reliable indicator of fishing use on a small trout stream because vehicles owned by nonfishermen were present in unpredictable numbers. Several studies (Lucas 1964a, Gibbs 1973, Chubb and Baker (article in these pro-ceedings)) utilized a double sampling approach to estimate use on rivers or in riverlike areas.

In contrast with dispersed-use situ-ations often encountered in terrestrial environments, rivers lend themselves, at least theoretically, to direct measure-ment or estimation of recreational uses. This advantage can often be exploited through another type of compound sampling scheme to yield quantitative data on several important parameters associated with river use. The strategy is to cor-relate the estimated amount of river use with selected activities *directly* associ-ated with this use. The rationale is similar to that used by fisheries mana-gers in quantitative creel censuses. Suppose, for example, that the number of rafts operating on a river is esti-mated by direct sampling. Interviews made concurrently among a representative sample of raft users could produce data for correlation with the estimated level of raft use to provide a measure of overnight floater camping, stops at points of interest, and other activities directly associated with rafting. Compound sampling has great potential for esti-mating visitor participation in a wide range of river recreation uses.

TECHNIQUES FOR ACQUIRING RIVER-USE DATA

Reporting Systems

Mandatory floater registration re-quirements and trip permit systems afford the ultimate opportunity for gathering and compiling complete use statistics. Sever-al State and Federal agencies have insti-tuted such programs on portions of the Colorado, Green, Salmon, Allagash, and Youghiogheny Rivers, to mention a few. Permit systems are administered on some rivers in cooperation with commercial outfitters or concession operators, an arrangement that can substantially reduce cost and administrative burdens on the managing agency. On the Allagash Wilder-ness Waterway in Maine, a user fee was recently incorporated into the registra-tion system to partially defray adminis-trative and maintenance costs (Cieslinski 1976).

The potential for comprehensive use data to be obtained through mandatory per-mit systems is perhaps best illustrated by Lime and Buchman (1973) who developed recreation-use statistics for the Boundary Waters Canoe Area in Minnesota. By analyzing travel permits issued to recrea-tionists entering the area, the authors developed 64 tables and figures presenting information on group sizes, time and place of entry, camping trends, watercraft use, etc. Back Country Use Permits have simi-larly been used to document both terres-tial and river recreation on portions of the Rio Grande River (Ditton *et al.* 1976). Noncompliance with permit requirements has not been a major problem on rivers where the managing agencies have been able to maintain effective access control. However, methods have been devised for measuring noncompliance and adjusting use estimates where necessary (Lime and Lorence 1974).

Voluntary registrations have been used only to a minor extent for documen-tating use on rivers. The main diffi-culty with this method is that incomplete responses hamper the development of re-liable use statistics. Hayden (1974) was able to verify an approximate 50 percent

response to a voluntary registration among private floaters on the Snake River in Grand Teton National Park, hence, a projection could be made for this category of users. Self-registrations have worked satisfactorily for estimating visitor use at developed sites on forest lands (Wagar 1969). Thus, voluntary registrations may have potential for wider application to river-use estimation if accurate calibrations can be established between recreation uses and registration responses.

Survey Techniques

Survey techniques have been widely used to secure data about river users and their participation in selected recreation activities. Included in this category are ground and aerial observation techniques, interviews, and survey questionnaires. Survey methods can be applied as the exclusive means for obtaining information, or they may be used in combination with counting devices.

Human observation, perhaps the most fundamental means for obtaining basic use data, has been relied upon in several studies. Hayden (1974) placed observers at two access points to record floater use on one heavily used portion of the Snake River. In a recent study on the American River Parkway in California, observations of recreation users were recorded by clerks walking or riding bicycles at 14 selected locations (U. S. Army Corps of Engineers 1976). This study relied on a Latin-square sampling design to inventory 12 categories of recreation use along 23 miles of river.

Recreation investigators have also relied heavily on visitor interviews as a means for obtaining quantitative river-use information. In many instances this has been done in conjunction with other data-gathering techniques. Interviews were used in combination with mechanical axle counters by Lucas (1964a) to estimate canoe use on the Quetico-Superior Wilderness, and by Chubb and Baker (article in these proceedings) during their investigation of recreational uses of the Pine River in Michigan. In other river-use studies, interviewing techniques have been supplemented with observations made from fixed-wing aircraft (Seitz and Dahlgren 1975, U. S. Army Corps of Engineers 1976). Similar techniques have been used to estimate recreation activities on reservoirs (James *et al.* 1971b). Aerial observations have also been recorded with the aid of photographic techniques (Kreig 1969). Some excellent work involving interview techniques has been done by Fleener (1971, 1975, 1976) to estimate recreational uses on portions of the Platte, Grand, and Mississippi Rivers. Fleener's use of a probability sampling scheme illustrates how interviewing techniques can be applied to measure diverse uses on complex river systems. Interviewing techniques were also used in a recent study of recreation uses on the Atchafalaya River Basin Floodway in Louisiana (Soileau *et al.* 1975), where more than 90,000 persons exiting through survey stations were contacted during the 3-year study.

Voluntary questionnaires have been used with modest success to obtain quantitative river-use data. James *et al.* (1971a) obtained an impressive 77 percent return of questionnaires placed on the windshields of cars belonging to trout fishermen along a small stream in South Carolina. This response was obtained with the aid of a questionnaire return box located nearby.

Remote Sensing Technologies

Much interest is developing in the application of remote sensing techniques for measuring river use. Mechanical, optical, and electronic devices are particularly effective for inventorying floater types of recreation. That is, automated systems seem best suited for recording traffic at specific points along river corridors.

A comprehensive review of remote sensing technologies and their applications in outdoor recreation research was made by Schell and Taft (1972). They concluded that aerial sensors, such as satellite systems and high altitude instrumentation, show little promise for providing data useful to recreation managers, the principal shortcomings being poor image quality and sampling disruptions caused by unpredictable weather. Ground sensors were believed to have potential for recreation data gathering, but high cost was cited as an obstacle to wide-

pread use of sophisticated electronic ensing systems. Hogans (1976) has made n excellent review of the current literaure on remote sensing applications in utdoor recreation research, particularly hotographic techniques.

Electric-eye devices have been used xperimentally for counting watercraft or heir occupants on several rivers, includng portions of the Brule[1] and Upper St. roix Rivers[2] in Wisconsin. Although the SDA Forest Service has successfully used lectric-eye devices to count canoeists n several Michigan Streams[3] such devices ave generally been plagued with problems f reliability and false counts. Several nvestigators reported equipment failures uring operation or complained of inacuracies caused when vessels running breast were not counted.

For several years the Bureau of Land anagement has used a commercially manuactured system relying on an electric-eye ensor to activate a movie camera. The evice has been used to monitor river raffic on portions of the Green River in tah.[4]

Time-lapse cameras have been used uccessfully to record recreational use n several rivers. Excellent results were eported by Marnell (1975) in the applicaion of a modified super-8 mm movie system o record floater traffic on portions of he Current and Jacks Fork Rivers in issouri. Similar results have been achieved by the USDA Forest Service on sections of the Eleven Point, Piney, and North Fork Rivers in Missouri.[5] A time-lapse camera system has also been used experimentally on the Buffalo National River in Arkansas (Babcock 1976). Sohn (1968a, b) and Haugen and Lenning (1970) utilized 8-mm time-lapse photography to record recreation activities on selected Iowa Lakes. Several studies of recreational and commercial vehicle activities on forest lands have also involved the use of time-lapse camera systems (Besse *et al.* 1974, Hogans 1976, Murphy 1973).

A sophisticated playback system for interpreting data recorded on super-8 films was recently described by Gasvoda and Besse (1975). Their automated traffic classifier consisted of a coded keyboard for tallying up to 10 categories of commercial and recreation vehicles projected on 8-mm film. Development of a similar system for use by river investigators could substantially increase the utility of time-lapse systems for counting and classifying traffic on rivers, especially those receiving intensive watercraft use.

Time-lapse camera systems offer several distinct advantages. The equipment is compact, relatively inexpensive, and can be located a sufficient distance from rivers to provide reasonable security. Traffic can be counted and classified, and watercraft moving upstream can be tallied separately from those going downstream. Another useful feature is that a time display can be incorporated into camera systems to show the distribution of traffic in time. With available films, 8-mm camera systems are useful only during daylight hours. However, this is not a serious limitation in most situations because rivers are used mainly during daylight hours. Possible invasion of privacy by photographic surveillance techniques has concerned some agencies (Marnell 1975). Hogans (1976) argues that such concerns are largely unwarranted as long as reasonable discretion is used in the application of camera technologies.

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[1]*Personal communication with r. Thomas A. Heberlein, Department of ural Sociology, Univ. of Wisconsin, adison, September 17, 1976.*

[2]*Personal communication with r. Henry Hughlett, National Park ervice, St. Croix National Scenic iverway, St. Croix Falls, Wisconsin, eptember 13, 1976.*

[3]*Personal communication with r. Dave Foster, USDA Forest Service, uron-Manistee National Forest, Cadillac, ichigan, August 3, 1976.*

[4]*Personal communication with r. Don Duff, Bureau of Land Management, alt Lake City, Utah, September 13, 1976.*

[5]*Personal communication with Mr. Marsh Lefler, USDA Forest Service, Mark Twain National Forest, Rolla, Missouri, September 10, 1976.*

Super-8 time-lapse photography has demonstrated considerable potential for river-use studies and further development of this technology appears well justified.

CONCLUSIONS

Recreation-use monitoring on rivers is a new endeavor. Because river corridors are physically diverse and varied in terms of the recreation they support, it is inappropriate to generalize about the application of use-measurement techniques. Specific methods must be evaluated individually in the context of their applicability and effectiveness under a given set of conditions. Rivers characterized by uncontrolled access, fragmented jurisdictions, and diverse recreation uses clearly require more sophisticated procedures for acquiring use data and impose correspondingly greater cost and logistic burdens than simple well controlled rivers.

Significant gains have been made in river recreation monitoring, but much room remains for improvement, particularly in reducing cost. Greater precision is needed for estimating use in complex river settings. This matter warrants high priority because many rivers designated or proposed for State river systems are extremely complex in terms of ownership, access, recreation patterns, and other factors that make use monitoring difficult. Improved sampling designs are needed to cope with a host of complications, including uneven distributions of use in time and space, complex activity patterns, and multidirectional traffic situations. Activities incidental to primary recreational uses are also becoming important management considerations that require data.

There is a need to improve automated counting devices for broader application in river environments, particularly time-lapse photo-surveillance systems. The potential usefulness of camera technologies is grossly underdeveloped. One caveat, however, is that remote sensing technologies should be used discretely. Unfavorable public reaction could eliminate a useful strategy for obtaining river-use data.

Finally, it is important for investigators to disseminate information concerning the application of new techniques for measuring river use. Developments in remote sensing technologies and advancements in sampling design especially should be reported.

RIVER RECREATION POTENTIAL ASSESSMENT: A PROGRESS REPORT

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ABSTRACT.--In the past, most river recreation was managed from the viewpoint of rectangular land areas rather than complete river systems. Managing from a river-oriented viewpoint gained momentum with the passage of the federal Wild and Scenic Rivers Act but no widely adopted method of assessing river recreation potential has yet been developed. Several approaches to potential assessment are summarized. The RIVERS Method, which is being developed by Michigan State University in cooperation with the North Central Forest Experiment Station, involves assessing 67 variables for each mile of river and evaluating the potential for 16 recreational activities.

APPROACHES TO PLANNING THE RECREATIONAL USE OF RIVERS

Society has recognized the recreation otential of rivers for many years. Public arks, private estates, summer homes, and variety of commercial enterprises have een located on rivers in order to take dvantage of the various psychological and ctive recreation amenities inherent in iver environments. However, until recently, ost individuals and agencies approached he recreational use of rivers in terms of imited rectangular land areas rather than iver systems. Even today, there are many nstances where river recreation is planned, eveloped, and managed with little or no hought for consequent downstream problems r upstream situations that may affect such se. Many planners and land managers still end to think only in terms of a particular ampground, park, or ranger district. Some ecreation potential assessment procedures, uch as the USDA Forest Service's recreation nventory, evaluate river potential by adinistrative unit. Unfortunately, the evelopment of even one facility such as a aunching ramp or logging road by one adinsitrative unit can drastically affect he recreational use of the river at other ocations. Similarly, policies regarding the types and amounts of recreational use permitted on one stretch of river often influence the recreational environment on other stretches. The rectangular viewpoint, therefore, can easily lead to user conflicts and unwise use of resources especially as participation increases.

River recreation planning and management based on a river-oriented viewpoint is generally much more satisfactory than planning or management founded on the traditional rectangular approach. River-oriented methods treat the river as a system rather than focusing on a particular tract or administrative unit. Individuals and sportsmen's clubs owning salmon or trout streams have long recognized the importance of controlling water quality and flow by watershed management. More recently, recreation values have been investigated on a watershed basis in the planning and management procedures of such organizations as the Tennessee Valley Authority, the U.S. Soil Conservation Service, and Ontario's river valley conservation authorities. However, in most of these cases, water control was the primary objective and recreation was considered a secondary benefit. Then, in the late 1960's, came the first large-scale attempts to preserve and manage rivers as

units because of their scientific and recreational values. Congress passed the Wild and Scenic Rivers Act in 1968 authorizing a national river protection program and many States followed with legislation that permitted protection of rivers with State-wide significance. River-oriented planning and management of waterways for recreation was receiving recognition at last.

RIVER RECREATION POTENTIAL ASSESSMENT METHODS

Although some agencies started to plan and manage river recreation from a river-oriented viewpoint more than 25 years ago, river recreation potential assessment is still in its infancy. Most evaluations have been for a particular site (such as a river-based State park site), for a specific administrative unit (such as a ranger district), or for one or two recreation activities (such as canoeing and camping). No large scale quantitative assessments involving a full spectrum of activities have taken place. This is unfortunate considering the great potential offered by rivers because of their wide distribution, the extensive range of water-dependent and water-related recreational activities that they can support, and the high carrying capacity of the water-land interfaces involved.

Techniques for objectively and quantitatively assessing their recreation potential are particularly desirable today when so many national, State, and provincial agencies are attempting to classify rivers. If many sizable river systems have to be classified, some type of numerical evaluation procedure is the only satisfactory approach. In this age of cost-benefit analysis and zero-based budgeting, planners and land managers can scarcely expect to defend plans for classifying and managing rivers on the basis of qualitative generalities; they need comprehensive quantitative support for their selections and priorities. It is no longer sufficient to announce in public hearings, environmental impact statements, and budget documents that a particular river is beautiful and should be preserved! Legislators, administrators, and citizens are expecting more these days and are unlikely to support classifications, rankings, and management plans that are not adequately supported by careful numerical analyses.

However, the absence of any widely recognized numerical evaluation technique is a problem. Most river evaluations are still being made on the basis of visits to selected sites or floating down and making brief qualitative notes on what is seen. This situation is rather like the early days of timber buying in the Great Lakes area when the "land lookers" or "timber walkers" travelled through the for gathering visual impressions and then advi their bosses what to buy. Just as forestr found it necessary to develop more reliabl forest inventory procedures, so modern rec reation planning and management needs systematic quantitative appraisal of complex recreation resources. During the past dec considerable progress has been made in dev oping such techniques for river recreation potential assessment.

The Craighead's Assessment Method

Probably the earliest systematic quan titative approach was developed by Frank and John Craighead in the early 1960's. Their evaluation system considered the potential for three activities: boating, hunting, and fishing. Ratings were based on scores for 12 variables for boating and hunting and 13 variables for fishing (Craighead and Craighead 1962). The scores possible for each variable were fro 0 to a maximum of 3, 4, or 5 depending on the variable. Scores were then summed for each activity and the totals used to indic a river's comparative suitability for that type of recreation. No weighting of one variable relative to others was employed other than the weighting inherent in estab lishing the scoring criteria and in settin maximum values at 3, 4, or 5.

The Leopold Assessment Method

Luna B. Leopold's method was designed to quantitatively evaluate and compare the esthetic quality of rivers in order to justify the designation of unique sections that deserve preservation (Leopold and Marchand 1968 , Leopold 1969b). He did no make evaluations for individual recreation activities but considered his esthetic evaluations were an indication of recreati potential.

Three groups of factors were consider in the Leopold method. One group was physical factors including valley topography,

iver width, and water velocity. Another roup consisted of biological factors such s surrounding vegetation, animals in the rea, and the flora and fauna of the river tself. Leopold's third group was called uman use and interest factors and included uch items as land use, accessibility, and istorical sites. He felt that unique andscapes were of greater significance to ociety than common landscapes so he used is evaluation scores to produce a unique-ess ratio based on how infrequently such onditions existed. This method has been riticized for not considering more factors, or employing an unnecessarily complex cal-ulation procedure, and for producing un-ealistic uniqueness values (Hamill 1974 , 975). However, Leopold's work was used s a starting point in many subsequent tudies such as Juurand's (1972b) work n classifying Canadian wild rivers and ibby's (1975) examination of the rec-eation potential of certain New Brunswick ivers.

The Dearinger Assessment Method

Both the Craighead and Leopold methods were developed for use on remote rivers in mountainous areas of the West. The first significant study in a more developed eastern environment was Dearinger's (1968 , 1971) investigation of the recreation and esthetic potential of small streams in Kentucky. He made his evaluation in two steps. First, the stream was rated for 92 natural and cultural variables and second, these ratings were used to develop scores for each of 16 recreational activities. Only the rating values for appropriate variables were used in developing each activity score, each rating value being multiplied by a weight based on the relative significance of the variable to the activity. The comparative suitability of each stream for an activity was then calculated by expressing the total score as a percent of the total possible score.

The Morisawa Assessment Method

A comparative study involving both eastern and western rivers was done by Morisawa (1971). She made extensive field observations including detailed transects of the main stream and main tributaries, and a reconnaissance survey of the entire water-shed while rating a river for its recreational and esthetic quality. In order to reduce the number of activities, she grouped them into three classes: active outdoor recreation, active water recreation, and nature observation and interpretation. Each transect was classified for each group of activities into one of four categories--(1) most or all activities in the group possible year round, (2) most or all possible seasonally, (3) some activities in the group possible year round, and (4) some possible seasonally. Esthetic quality was measured by rating such features as vegetation, relief, water appearance, pollution, and litter on a 5-point scale. In a subsidiary project, an attempt was made to develop empirically based values for esthetically important features by showing 45 color slides of river scenes to 500 individuals and asking them to evaluate their beauty on a 6-point scale.

MacConnell and Stoll Assessment Method

A very different approach was used by MacConnell and Stoll (1969). They assessed the recreation potential of the Connecticut River by mapping land use from aerial photographs. The uses classified were 9 types of agricultural land or open space, 6 types of mining land, 12 urban types, 14 recreation facility types, and 26 riverbank and rivershore types. They also considered accessibility, picnic and camping areas, scenic overlook sites, aquatic vegetation, physical obstacles in the water, and other factors affecting recreation participation.

Other Assessment Methods

The studies outlined above are those that we found of greatest relevance in developing an approach to river recreation potential assessment. However, there are many other studies and planning procedures that include useful ideas such as the USDA Forest Service technique for making forest-wide inventories of recreation potential (U.S. Department of Agriculture 1972), the Northern Region's method of using portions of valleys as "recreation experience units" when assessing recreation opportunities in the Rocky Mountain area (U.S. Department of Agriculture 1974b), and Olson's (1969) use of aerial photographs to estimate boating, swimming, and camping potential on township-sized areas.

The experiences of some of the States and Provinces in developing classification systems are also relevant. More than 25 now have classification systems and 9 use numerical scoring methods. However, most systems are simple techniques based on general esthetic appeal and impressions concerning suitability for canoeing. The Bureau of Outdoor Recreation is developing a method of evaluating rivers for inclusion in the national Wild and Scenic Rivers system but it, too, is based more on the esthetic and heritage values of rivers than on detailed analysis of potential for a variety of recreational activities. In Ontario, the Ministry of Natural Resources is developing a technique for assessing river corridors as possible sites for a new type of provincial park called a waterway park (Ontario Ministry of Natural Resources 1976). It involves rating a possible location for 17 variables on a 5-point scale. These variables include the time it takes to canoe the proposed stretch, navigability, diversity of conditions, carrying capacity, water quality, and conflicting activities. Further discussion of relevant methods is contained in a thesis by Bauman (1976).

DEVELOPMENT OF A DESIRABLE METHOD FOR THE USDA FOREST SERVICE

In 1975, the Department of Geography, Michigan State University, began a study of river recreation potential assessment methods for the North Central Forest Experiment Station. The basic goal was to develop a method that could be used to objectively classify rivers and plan their recreational use over large geographic areas such as a national forest or State. The technique selected would therefore have to be applicable to a wide range of rivers from wild rivers in remote mountain regions to placid rivers in agricultural and urban areas. After careful examination of previous methods, discussions with a number of agency personnel, and some preliminary field work, we developed an approach called the RIVERS Method (*R*iver *I*nventory and *V*ariable *E*valuation for *R*ecreation *S*uitability). This technique was then given a limited field test on four sections of three different rivers in Michigan during the summer of 1975. We are now planning a much more extensive field test of a modified RIVERS Method. These tests will involve practical application of the technique by agency personnel at a number of locations in the United States and Canada.

BASIC FEATURES OF THE RIVERS METHOD

The method has five basic features that, in combination, distinguish it from previous techniques: (1) it evaluates river environments for 16 different recreational activities, (2) this evaluation involves a broad range of pertinent natural and cultural variables, (3) it is applicable to rivers of all types from precipitous torrents in remote wilderness regions to slow-flowing rivers in highly urbanized areas, (4) it uses computer programs to facilitate computations, and (5) it permits quantitative comparisons between rivers of various types or between segments of the same river or different rivers.

Office Inventory

The first step in the RIVERS procedure is to gather all available pertinent information regarding the river to be studied. A key item is a set of suitable aerial photographs. Good quality color-infrared photographs at a scale of 1:36,000 or larger is desirable but conventional panchromatic black and white or infrared black and white are acceptable. The river is then marked off in 1-mile long segments measuring down the center line of the river. As much data as possible is then compiled on a separate inventory form for each segment. The variables included on the inventory form are as follows:

Basic Physical Features
- width of river
- site development potential
- apparent stream velocity
- floatability
- flow fluctuation
- seasonality
- stream bed materials
- dominant river pattern
- water surface pattern
- bank erosion

Special Physical Features
- ponds
- sandy beaches
- oxbow lakes
- immediate bank height
- bayous
- islands
- navigational obstructions

General Water Quality
- turbidity
- temperature
- bottom solids
- floating solids
- bacteriological condition
- chemical pollutants
- pesticides
- odor

General Soils Limitations for Recreational Use
- conditions that limit dryland activities such as camping

Biological Features
- algae
- water plants
- fish
- waterfowl
- land flora
- game animals
- other animals
- other birds

Land Use
- general land use
- historic sites
- public ownership

Esthetic Features
- scenic variety
- general beauty
- unique features
- remoteness
- trash
- detrimental structures

Accessibility
- roads, trails, ownership, and other aspects of accessibility

More details concerning variable specifications and a copy of the inventory form are part of our final report to the Forest Service (Chubb and Bauman 1977). Most of the data are concerned with features within the "river corridor"--an area we defined as extending ¼ mile on either side of the center line of the river. Most of the variables are scored on a 5-point scale with the higher numbers assigned to conditions favorable to recreational use. Some variables can be rated in the office by stereoscopic interpretation of the photographs. Others such as water quality and ownership can be rated from agency reports and maps.

Field Inventory

The second step is to float the river and complete the inventory by field observation. An ideal arrangement for small- and medium-sized rivers is a three-man party. The observer uses the air photographs and topographic maps to establish their position and checks the inventory sheet as they proceed down each segment.

Data Analysis and Evaluation

When all the data have been recorded on the inventory forms and carefully checked, the field crew turns in the forms for the analysis and evaluation phase. The information is punched on data processing cards and used as an in-put to our RIVERS computer program. At present, the program is designed to make simple arithmetic calculations for each of the following 16 recreational activities:

- Bank fishing
- Boat fishing
- Canoe camping
- Driving for pleasure
- Hiking
- Hunting
- Nature study
- Picnicking
- Power boating (10 h.p. or more)
- Small craft boating (under 10 h.p.)
- Social canoeing
- Swimming
- Trail camping
- Vehicle camping
- Waterskiing
- Wilderness canoeing

First, it selects the variables that are appropriate for evaluation of the river's potential for a particular recreation activity; for example, only 41 of the 67 variables for which a rating is recorded are used in assessing the potential for hunting. Values for the selected variables are then "transformed" depending on whether or not a variable has a positive or negative correlation with the activity concerned; for example, rapids are generally regarded as positive for wilderness canoeing but negative for boating with large boats. In the next step the transformed values are multiplied by numbers (termed "weights") that reflect the importance of each transformed variable in determining the feasibility of each activity.

Finally, the program sums the weighted scores for each variable and expresses the total as a percent of the maximum possible. The percents are then compiled into a matrix by activity and river segment and plotted

on a map. At present, we are using manual mapping procedures but, when further field tests of the inventory technique have been completed, a computer mapping routine will be developed. Eventually, when a number of typical rivers in various classifications have been evaluated, the computer program will be extended to include classification of the river as a whole and by major sections, and the calculation of a ranking in relation to other rivers in the same class.

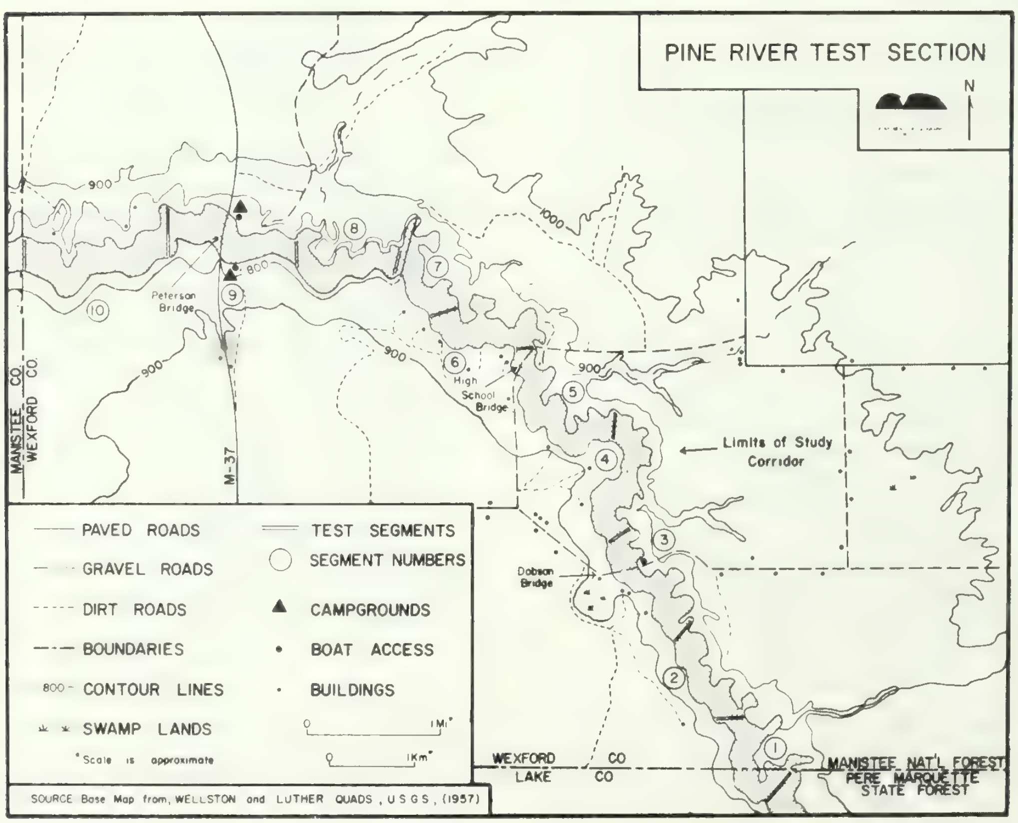
Test Rivers

We made an initial test of the RIVERS Method by gathering and analyzing data for four sections of three Michigan rivers. One 10-mile test section was on the Pine River near Cadillac in Wexford County (fig. 1). Two 11-mile sections were on the nearby Manistee River. Both the Pine and the Manistee Rivers run through the Manistee National Forest and are well-known canoeing rivers. However, we were looking for a variety of conditions so a section of the Manistee that is severely affected by water discharge from a power station and a relatively flat section near the mouth were selected. The fourth test section on the Looking Glass River was 10 miles long; it flows through agricultural land with considerable streambank housing development and is within 10 miles of the Lansing-East Lansing metropolitan area.

CONCLUSIONS CONCERNING A DESIRABLE METHOD

From our experiences in developing and testing the RIVERS Method we came to the following conclusions regarding the features that are necessary for a technique to be effective in classifying and planning the recreational use of a large number of rivers

Figure 1.--*Diagrammatic map of the Pine River test section showing the river corridor and 10 segments*



Number of Recreational Activities Considered

After careful examination of previous ethods and experimentation with several oupings of activities, we concluded that e only practical approach was to treat l the principal uses of rivers as separate tivities. One of the problems of managing pular rivers like the Pine River is the nflicts between the resource needs and havior patterns of the various user oups. For example, on such rivers the noeists conflict with the fishermen. itting either of these activities is rtainly not appropriate and combining em into a group hides the conflicts and ggests there are no differences in resource eds. Similar problems occur with other pes of rivers and activities if omissions groupings are attempted.

Number of Variables Included in Inventory

Although one instinctively wishes to educe the number of variables included in e inventory, our experiences did not incate that the elimination of one or more practical at this stage. The variables e numerous and complex but so are the creational uses of rivers and the interlations between the resources and user ehavior. When more rivers have been asessed, it may be possible to empirically etermine the relations between river atures and recreational use. Behavioral tudies may also assist in establishing ese relations if they are sufficiently omprehensive. In the meantime, rivers are eing classified, planned, managed, and, in ome cases, abused so the use of intuitively eveloped inventory variables is the only olution.

Scoring and Weighting Procedures

The five point scoring system worked atisfactorily in the field; little difficulty was experienced in deciding which core should be assigned for a particular ariable. However, the scoring and weighting rocedures were developed intuitively and ill also benefit from further experience ith the method and data from comprehensive ehavioral studies. We found, for example, hat in some cases the negative effects of low-lying poorly drained soils did not reduce the scores for river bank activities as much as conditions warranted. Accessibility and navigational obstructions also did not have as strong an influence as desirable. Another problem was an apparent lack of differentiation between the potential for some activities on high quality rivers compared to low quality rivers. We plan to include evaluation of sample stretches of lower quality urban rivers in future field assessments in order to determine what alterations in the scoring or weighting are appropriate.

Assessment of Entire River and Segment Length

We found that the use of transects or sample segments is not satisfactory. For example, canoeing and boating are greatly affected or even eliminated by river obstructions; if a small river runs through heavily wooded terrain, it is often difficult or impossible to assess river navigability from aerial photographs because of the foliage or deep shadows. If only certain parts of the river are assessed by field inspection, it may be over-rated for navigability.

We found that the mile-long segments worked well. Although longer segments would reduce the number of inventory forms and simplify all phases of the analysis, retention of visual impressions and agreement on assessment scores often became difficult if segments were longer than 1 mile. On the other hand, use of shorter segments slowed down the assessment process and greatly increased the duration and cost of analysis without adding significantly to the apparent validity of the ratings.

Quantitative Significance

We have no illusions about the quantitative significance of assessment scores obtained by the RIVERS Method. We found it difficult not to include complex and precise measurements such as averaging a series of rangefinder readings to obtain channel width or using a secchi disc to measure water turbidity. However, the objective is to evaluate many rivers in a short time and any method that meets these specifications is bound to involve

numerous approximations. The final evaluation scores, therefore, are not precise values. Rather, they are quantitative generalizations of the type made in classifying climates or calculating site indices. The reliability of the method is thus primarily a matter of how consistently different observers arrive at approximately the same scores for a particular river segment. This will be tested more extensively in the future but fieldwork to date leads us to believe that the method produces reasonably consistent scores.

Applications

In addition to facilitating decisions regarding the recreational use of rivers flowing through forest lands and the classification of rivers under National, State, and Provincial programs, numerical assessments such as the RIVERS Method have a number of other potential uses. They would be helpful in preparing environmental impact statements for projects involving river land such as the building of dams, channel improvements, or riverside highways. In such cases, it may prove possible to stimulate what would take place if an inventory was performed following completion of such projects and produce anticipated final recreation potential scores. Comparison of the latter with the current scores would give a quantitative impression of the probable impact. Another possible use would be to demonstrate the effects of decreasing water pollution or the changes resulting from improved urban river environments. In any event, use of such quantitative evaluations will draw attention to the recreation potential of rivers and should result in more careful allocation of these valuable recreation resources.

FURTHER DEVELOPMENT

During the next phase of developing the RIVERS Method, we plan to address the problems mentioned above and also include some other secondary investigations. A limited experiment on the Pine River indicated that 35 mm color photography from a light aircraft may be useful especially where no other suitable air photographs are available; this will be investigated further. We also plan to study the possibility of including more extensive consideration of carrying capacity in the inventory and analysis procedures. However, field testing the method on a number of different kinds of rivers will be the main objective of future work.

ACKNOWLEDGMENTS

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ALTERNATIVE STRATEGIES FOR STUDYING RIVER RECREATIONISTS

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ABSTRACT.--Recreation researchers have a variety of social research tools available to them. Often, however, the application of alternative tools in studying recreation issues is inconsistent with the relative strengths and weaknesses of the procedures. Altèrnative research strategies are discussed in terms of their ability to provide information to answer basic questions about recreationists and recreation problems. Implications for planners, managers, and policymakers are addressed.

Understanding recreational problems and the motives, preferences, values, and behavior patterns of recreationists is an important concern for recreation managers and researchers. Such understanding is essential for identifying the consequences of alternative recreation management strategies.

Recreation researchers have a variety of social research tools available. Often, however, the application of alternative tools in studying recreationists and recreation problems is inconsistent with the relative strengths and weaknesses of the procedures. The need for accurate, unbiased information is essential for the development of effective recreation policies and management schemes. Therefore, recreation planners, managers, and policymakers should be as concerned as researchers that appropriate research procedures are followed.

The purpose of this paper is to describe alternatives to the traditional cross-sectional survey and present a framework for selecting *when* a specific data collection strategy may be appropriate or inappropriate. The framework allows the researcher to examine the alternatives in terms of the information they can and cannot provide. Such a framework should also prove useful to planners, managers, and policymakers because it gives a basis for evaluating whether the data developed in a study answer specific questions about recreation phenomena.

My discussion focuses on providing a general overview of when and why each approach may be best. These comments are as applicable to the study of river recreation (the subject of this symposium) as they are to any other setting. Readers interested in more detail are referred to the readily available social research methods textbooks and papers, only a few of which are referenced in this paper.

BASIC RESEARCH QUESTIONS ABOUT RECREATION BEHAVIOR

Two fundamental types of questions that researchers and policymakers might ask about recreation behavior are: (1) questions requiring description and (2) questions requiring explanation.

Good description is the key to understanding and is often neglected in social science research. Three basic descriptive questions for which researchers or policymakers might seek information are:

1. *Description of the event: What is happening, when, where, and how much?* Answering this question involves a basic description of the event being studied. For example, the researcher may want to know how extensive river use is and how

it varies from location to location or by time or season.

2. *Description of the participants: Who is involved?* Describing the social, physical, and psychological characteristics of the persons involved in the event under investigation will answer this question. For example, who rafts? The young? The old? The highly educated? Groups or individuals?

3. *Description of preferences: What do people prefer?* Most people make a variety of choices daily in keeping with their personal values and goals. Describing the various preferences for types of recreation--for example, desirable developments, acceptable management procedures--is central to both understanding and providing for recreation opportunities.

After a phenomenon has been adequately described, the next step is to explain why it occurs. Two general questions relating to the explanation of a phenomenon are:

4. *Explanation of an event: Why is it happening?* This involves an explanation of the phenomenon in terms of either participant motivation or various components of the environment. For example, can visits to a specific river be explained by the user's desire to be there, or by the fact that few alternatives exist for that kind of experience? Why do people choose one area over another? Why do they continually violate well-posted rules?

5. *Explanation of change: How can behaviors be modified or changed?* Answers to this question are often necessary for producing desirable results in recreation areas as well as other areas. Changing (or maintaining) a certain behavior is often the desire of the resource manager who may be faced with problems of overuse, litter, vandalism, sanitation, conflicting uses, or intolerable resource damage. Information provided in answer to earlier questions is often essential in preparing a study to answer this final question. Examples include: How can littering or vandalism be prevented along rivers, and what procedures will effectively disperse users along popular stretches of streams?

RESEARCH DESIGNS AND DATA COLLECTION STRATEGIES

In preparing a study to answer one or more of the above questions, the researcher must choose from a variety of research designs and measurement strategies. A research design is the basic framework within which data are collected; that is, are the data about the same population collected only once (cross-sectional design) or more than once (longitudinal design)? Or does the investigator attempt to determine "cause and effect" relations through some control procedure (experimental design)? Measurement strategies are the various procedures by which data are collected. Does the researcher look for himself (observation) or are subjects asked to speak for themselves (self reports)? Any study is a combination of a research design and measurement strategy; for example, a cross-sectional survey, a longitudinal observation study, or an experimental design using direct observation as a measurement strategy.

Research Designs

1. *Cross-sectional.*--This design is characterized by one measurement of the phenomena in question across a segment of the target population. It allows for intersubject comparisons on the characteristics or behaviors measured.

2. *Longitudinal.*--This design allows for measurement of attributes or behaviors within a target population two or more times (also known as panel or time-series studies). It allows for intrasubject as well as intersubject comparisons over time.

3. *Experimental.*--This design is characterized by some sort of manipulation or control procedure by the investigator and an evaluation of its effect on the phenomenon in question--did the manipulation result in any change in attitudes or behavior?

Measurement Strategies

1. *Observation.*--Observation refers to systematic techniques for observing, recording, and evaluating behavior. Such observation follows specific procedures and is much more exhaustive and objective than casual observation done in the

urse of normal events by both managers nd participants. There are three methods or observation: direct observation of vents as they occur, observation of traces f behavior, and participant observation.

2. *Self reports from subjects.*--The ubjects under study can be asked to report he desired information to the investiga- or. Essentially, this requires the sub- ects to "observe" their own characteris- ics, behavior, or feelings about what they o or events that go on about them. The ools used in this approach are surveys interviews or questionnaires) and diaries.

ADVANTAGES AND DISADVANTAGES OF ALTERNATIVE RESEARCH DESIGNS AND MEASUREMENT STRATEGIES

From the researcher's perspective, nswers to all five basic research ques- ions are important for an understanding f a particular recreation phenomenon. ractically, however, some questions may be ore important than others. Managers, for xample, are often concerned with main- aining or modifying certain behaviors question 5). Unfortunately, no single ombination of a research design and mea- urement strategy will provide data to nswer these questions. The method of tudy must be selected with two criteria n mind: (1) Will it provide reliable and alid information to *directly* answer the uestions? (2) Will it provide the infor- ation efficiently?

Table 1 summarizes the relation between the basic questions and alternative research designs and measurement strategies. The basic assumption is that the design and measurement strategy is acceptable *only* if it can provide valid and reliable data to answer the question directly. Therefore, conjecture and inferences based on data collected to answer other questions may not be appropriate for judging the utility of the method under consideration, particularly if there is a better alternative.

Readers should refer to table 1 during the following discussion about the advantages and disadvantages of alternative research approaches.

Alternatives for Questions of Description

The Cross-Sectional Survey

The cross-sectional survey is the standard social science tool used in most recreation research. Indeed, it is the most common method used in all social science research. The pros and cons of using this method are presented first to serve as a baseline for comparing the other methods.

Three kinds of information are typically sought in a survey: (1) Respondents are asked to recall their past behavior (or to predict future behavior); e.g., how many trips they've taken to a certain river. (2) They are asked to report descriptive characteristics such as income, education,

Table 1.--*Relation of research designs and measurement strategies to basic questions about recreation behavior*

Basic questions about recreationists and recreation behavior	Research designs			Measurement (data collection) strategies						
				Observation			Self reports			
				Systematic			Surveys			
	Cross-sectional	Longitudinal	Experimental	Direct	Trace	Participant observation	Behavior recall	Report of characteristics	Report of attitudes, beliefs, etc.	Diary (log)
Description:										
1. What is happening--when, where, how much?	X	X		X	X	X	(X)			X
2. Who is involved?	X	X		X	(X)	X		X		X
3. What is preferred?	X	X	X	(X)	(X)	X	(X)		X	(X)
Explanation:										
4. Why is it happening?	(X)	(X)	X	X[1]	X[1]	X			X	X
5. How can it be maintained or modified?			X	X[1]	X[1]	X[1]	(X)[1]			(X)[1]

[1] Appropriate within an experimental design.
X = Acceptable alternative--provides data to directly answer the question.
(X)= Acceptable under limited conditions.

age, sex, place of residence, and similar items. (3) They are asked to report individual psychological states, attitudes, preferences, and beliefs about such things as wilderness, rivers, recreation, and society. Items like "I believe there is a crowding problem along the river; I prefer solitude at my campsite; or I think people should pick up the litter of a friend"; are examples of such measures. Each of these types is examined below.

1. *Behavior recall.*--Behavior recall is often used in surveys to answer the questions, "What is happening?" and "What is preferred?" Because of the serious shortcoming of this approach, behavior recall is a poor substitute for other methods. Behaviors recalled on a questionnaire or interview are likely to be an inaccurate measure of actual behavior. In studies of littering, for example, more than 50 percent of people observed littering said they had not (Heberlein 1971). Several factors probably account for the discrepancies observed. A common human frailty is our inability to objectively record our own behavior even under the best conditions (Mead 1964), and particularly the motivations behind it. People may simply not know or may forget what they did or when they did it. They may think events happened more recently than they actually did. Definitional problems also may operate--asked how many times one has visited rivers in wilderness areas, a person may count trips to areas which really aren't wilderness. And, as in the case of not reporting littering behavior, people are reluctant to admit illegal or inappropriate behavior and deliberately mislead the investigator.

2. *Reported characteristics.*--Asking subjects to report various personal or group characteristics is straightforward and is usually a part of most surveys. Requesting this information is usually secondary to asking about their behavior or attitudes. Many personal characteristics, although not reported without error, are sufficiently accurate for most purposes, especially when the high cost of determining such information by other means is considered.

Reported characteristics included in a questionnaire or interview give a description of many unobservable as well as observable variables related to individuals and groups ("Who is involved?"). Whether or not this measure of "who" is appropriate depends on how involvement in the event under study was determined. If involvement is based on self-reported behavior recall data, then relations between "who" and "what" may be questionable. If, however, the investigator has some prior knowledge about actual involvement in an activity (direct observation, use registers, licenses, etc.), the sample can be restricted to those known to be involved in the event of interest. Such a description of "who is involved" is more likely to be accurate than the former. Generally, the results of broad surveys directed at an unidentified population must be viewed with caution.

3. *Reported attitudes, preferences, and beliefs.*--The focus of most surveys is on respondents' attitudes, preferences, and beliefs. This approach is not without serious problems as has been well documented in the social science literature (Heberlein 1973). Attitudes are conceptually complex and difficult to measure. An attitude survey often appears easy to carry out but in fact requires a great deal of skill in conceptualization, measurement, and analysis (Potter *et al.* 1972).

Further, it sometimes appears that attitude studies are done when people are really interested in behavior and the implicit assumption has been made that attitudes closely approximate real behavior. But, there is little evidence of a direct effect of attitudes on behavior (Deutscher 1966, Hancock 1973, Heberlein 1973, Wicker 1969). Wicker's (1969) study showed that attitudes predicted real behavior only 10 percent of the time.

A basic question for which attitude studies are appropriate is, "What do people say they prefer?" From a carefully conducted attitude survey of the appropriate population, a manager may accurately assess what people say they prefer. Stankey (1973) showed how wilderness purists prefer different wilderness management policies than nonpurists do. He argued that such preferences should be taken into account in wilderness management.

Attitude studies allow people to assess and consider hypothetical alternatives which do not exist. However, this hypothetical nature of the alternatives

esents its own difficulties. We may be eveloping and managing recreation areas n the basis of hypothetical answers to ttitude questions not representative of he real world.

lternatives to the Cross-Sectional Survey

Alternative measurement strategies: elf reports--diaries.--This self-report rocedure requires that participants record heir own behavior, feelings, etc., as lose to the time they occur as possible. s the name implies, diaries are kept over n extended time period, such as a float rip down a river. Respondents may be sked to record their motives for doing hings as well as what they did. Diaries re particularly useful for gathering information about people while they are raveling to remote locations such as long rivers or when their travel prevents asy observation. The reduced time lag, ompared with that of surveys, compensates o some extent for the inaccuracy of behavior recall described earlier.

The diary approach has many of the aults of other self-reporting procedures. or example, only normative behavior is ikely to be recorded completely and accurately. Inconvenience also may prompt ncomplete entries. Even with its faults, he diary is a procedure that must be considered when information over a period of ime is wanted. With proper instructions o the respondent, many of its shortcomings can be reduced.

Diaries can be useful for determining "hat is happening". Diaries have been uccessfully used by State fish and game epartments to study fishing and hunting ctivities and by researchers to study ilderness travel (Lime and Lorence 1974). iaries should include appropriate instruction for what to record, how to enter nformation, and when to log the entries. iaries are best used when the investigator an specify things he wants documented; for xample, "When and where did you camp along he river?" "Who were you with?" "What did ou do in the evening?" "How many other oating parties did you encounter?" Requesting that "everything you do" be recorded, over even a short period of time, s usually unworkable and puts an unnecessary burden on the respondent.

Diaries can yield accurate information about "who is involved" in an event. This information about "who" is similar to that provided on questionnaires and interviews, except that the information is recorded presumably as the events occur rather than recalled later.

Alternative measurement strategies: observation methods.--(a) *Systematic observation of events as they occur.* For this form of observation, the specific events or objects under study must be well defined and directly observable. This method can be conducted by an observer who tallies specific events or notes certain objects by some prearranged coding schedule. Or it can be done by artificial surveillance such as remote cameras and other automatic recording devices. Examples of events susceptible to this approach include various human behaviors such as the amount and type of use a facility, area, trail, or river receives.

Systematic observation of actual behavior in recreation settings has several problems. First, the measure may be reactive; that is, the presence of an observer may affect the behavior under study. For example, measuring littering behavior by placing observers along a trail is likely to reduce the incidence of the behavior, because people tend to litter more when they are alone (Heberlein 1971). Therefore, even if observations of behavior are reliable, they may be invalid because of the reactive distortion caused by the measurement process itself.

A second and more serious problem for the outdoor recreation researcher is that systematic observation of actual behavior may be inefficient and expensive because some behavior is difficult to observe or seldom occurs. In remote settings it may take many hours to record a few observations because of infrequent and scattered use.

A third area of concern regarding systematic observation is observer reliability (Burch 1974). Without specific training for the observer, pretested recording schedules and instructions and continual reliability checks, a serious distortion of actual events can result. Indeed, the observer is both the strength and the weakness of this approach (Kerlinger 1973).

When events are well defined and directly observable, systematic observation will produce reliable, valid, and accurate results about "what is happening"--if the problem of reactivity can be overcome. A definite advantage of this procedure is that with proper sampling, generalizations can be made about specific individual and collective behaviors.

Systematic observation of events can also describe "who was involved". Variables such as the subject's sex, race, age, etc., can easily be recorded at the time the event is observed. The only criterion is that "who" be clearly identifiable.

Systematic observations of events as they occur can sometimes provide data to answer the question, "What do people prefer?" For example, observation focusing on where people choose to camp along a certain river may reveal a preference for locations far from other sites. However, the correlation between the presence of other sites and actual preference may be spurious. Perhaps the locations were selected because of some other quality, such as availability of sunlight or nearness to a good landing. Some other procedure (such as a survey or diary) will be necessary to clearly establish the reason for the choice.

(b) *Systematic observation of behavioral traces.* Observing the effects of previous behavior may be appropriate in some cases. Observation of traces is one way to reduce costs of direct observation and to obtain nonreactive measures because the subjects under study need not be present when data are collected. Webb *et al.* (1966) described a wide array of such unobtrusive measures.

Accretion of or buildup in environmental factors caused by human behavior are a good measure of such behavior. For example, how much litter accumulates at sites along a river? Although these measures may be unreliable because of weather factors, they are valid and relatively inexpensive. Measures of the degradation or erosion of the environment are also useful. The rates at which trails are wearing down or firewood and foliage are disappearing are measures of the amount of use an area receives. A wide array of such traces may be regularly recorded in and around a recreation area by the creative investigator.

An important difference between traces and other measures of behavior is that traces usually indicate aggregate behavior rather than individual behavior. This limits the generalizations that may be made from the resulting data. From actual observation of rafting behavior and sex of the rafters, the investigator can correlate the subjects' sex and rafting activities. Such a correlation cannot be made from traces.

When individual events need not be or cannot be observed directly to determine "what is happening", measuring their traces may be useful. By systematically observing the accretion or degradation of a variety of factors that occur as a result of recreational behavior, a measure of its impact can be determined. Such aggregate data may be sufficient for planning and policy purposes.

Trace observation can yield information about "who was involved", although validity and reliability must be seriously questioned. The presence of discarded fish bait containers and fishing gear wrappers suggests that fishermen were in the area; the presence of horse droppings or feed hay at campsites suggests that horse users were there. The precision with which such data can be measured, however, may limit its usefulness. And, because traces are a measure of aggregate rather than individual behavior, the investigator cannot determine from the above example if fishermen or horse users were the only people in the area, nor if the fishermen came on horseback. Interpreting and generalizing such data are difficult, but for some purposes, the knowledge that fishermen or horses were in the area may be enough.

Use of traces to determine "what is preferred" suffers from all the shortcomings of direct observation, plus those inherent in measurements of accretion and degradation as reflectors of previous events. This method should be used only when alternatives have been ruled out.

(c) *Participant observation.* As Campbell (1970) points out, participant observation is more than a single method of data collection and may include a variety of techniques for gathering quantitative

nd qualitative data. This method is unobrusive and relatively inexpensive. Some riters include systematic observation as a articipant observer's role (Campbell 1970, old 1958). For the purposes of this aper, discussion of this procedure is imited to roles involving interaction with articipants. That is the essence of participant observation which distinguishes it rom the other forms of observation.

The method is difficult to define imply, but it generally involves the inestigator directly taking part in the ctivity he wishes to study. The observer s able to observe his own reactions to vents taking place as well as reactions f others. Through this interaction with articipants and continual data processing nd evaluation, the investigator can reormulate the problems as the study proeeds and look for new information (Dean *t al.* 1969).

Major disadvantages of participant bservation include the possible lack of bjectivity and reliability of the oberver, the possibility of becoming overhelmed with large amounts of information, eactivity if the identity of the observer s known or suspected, and insufficient nformation collected for generalizing ecause it is often subjective and incomlete. Systematic theory testing requires ore rigid procedures.

Participant observation is often useul as a prelude to surveys or more systematic counting of objects, specific events, r behavioral traces. Operating as both bserver and participant, the investigator an gain insights that might not otherwise e apparent. Participant observation is n excellent and efficient tool for defining the dimensions of a problem because a reat deal of diverse information can be uickly generated.

In the early stages of a study, participant observation is useful for determining "what is happening" at a broad level--the range of events, type of participants, activities, problems, etc. A ajor advantage of this method is that the bserver is often able to gain access to vents, because he is involved in them and oes not pose a threat to people being bserved.

Participant observation gives a clear picture of "who is involved" in events that the observer sees. Finding out who was engaged in events not observed is also possible by talking with others. The participant observer often has access to information about "who is involved" because he is more readily accepted as a member of the group than a formal observer or authority. Thus, data on "who" result from what is seen and what is learned from others.

Participant observation should also be considered an important alternative in the study of "what is preferred"--particularly in the early stages of an investigation. The observer learns about preferences by several methods--his own and other people's choices (for example, where to camp along a river) and informal talks with them to determine what they prefer. Initially, participant observation may help determine the range of preferences, but a more systematic process would best determine their relative importance.

Alternative research designs : 1. longitudinal design.--In addition to the problems with the survey measurement strategy, the cross-sectional design of many studies limits the generalizations that can be made from the data. With events measured only once, intersubject comparisons can be made across the population at that time only. With a longitudinal design (measurements of the same population two or more times), both intersubject and intrasubject comparisons are possible over time, and descriptive questions can be more readily answered. As an alternative to the cross-sectional design, longitudinal design of studies can clearly identify trends over time, if disadvantages of the measurement procedure are considered. Longitudinal designs, however, impose greater burdens on both researcher and subject because data are collected more than once (Crider *et al.* 1973).

Alternative research designs : 2. experimental design.--In essence, an experimental analysis is a longitudinal design with some manipulation occurring between measurements. Data are collected by observation or a self-reporting procedure. The element of manipulation and before and after measurements make this process unique.

Although few experiments are reported

in the literature on recreational behavior, many experiments are actually done but without sufficient documentation to determine effectiveness. In day-to-day decisions, managers and policymakers initiate changes in recreation environments which may have some effect on people. For example, they may provide trash cans along a river, build a new road for boat launching, develop more campsites, add convenience facilities, or restrict access. The manipulation or change is essentially the guts of an experiment. The impact of the change needs to be evaluated so that the desired results will be attained. More attention should be paid to documenting cause-effect relations implicit in most management actions to ensure that undesirable consequences do not occur. For example, as Clark *et al.* (1971) illustrate, the process of "creeping campground development" in response to increasing use may have serious effects on the types of users attracted to certain areas.

An experimental design may be useful for providing data on "what is preferred". Direct observation, and to some extent self-reports (even if done within a longitudinal design), will provide partial answers on how people behave or their stated preferences. However, these approaches may have serious errors. To determine exactly which factors influence choice implies some sort of experimental design. By systematically controlling or manipulating characteristics of river campsites, for example, and measuring the effect, researchers and managers could identify important factors related to site preference and, more important, their use.

Alternatives for Questions of Explanation

The Cross-Sectional Survey

The cross-sectional survey may be best suited to answer the question of "Why things are happening", particularly when the answer may require a social-psychological explanation. A carefully conducted survey of attitudes can explain why the phenomenon occurred in terms of the social psychology of the action and the mediating decision process. To do a study of attitudes presumes that one knows a great deal about the process itself, but many attitude studies seeking to learn why something is occurring don't seem to have this understanding. Such studies are no by a wide variety of unrelated questions the lack of clear research hypotheses pr to data collection, and the general ster ity of results. Further, when trying to explain why a behavior is occurring or h to control it, an attitude study may be inappropriate because situational or environmental factors may be largely responsible, and these are generally ignored in most surveys.

The cross-sectional survey is inapp priate for determining "how a behavior c be modified or maintained". Research on litter control by Keep America Beautiful Inc. (1968) presents a good example. Respondents to a survey identified two classes of reasons for littering. The first type was individual attributes--laziness, indifference, carelessness, et But this description doesn't really tell us why littering occurs because these da say nothing about the process linking su attitudes to littering behavior. The second class of reasons relates to situational factors--trash facilities, litter bags, etc. The problem here is that littering itself was not under study. Respondents were asked to give reasons why they think littering occurs or how i can be controlled. Whether or not facil ties, laws, litterbags, and education ha anything to do with the respondents' pas present, or future littering behavior ca not be ascertained from this type of stu Indeed, other research (Clark *et al.* 197 Heberlein 1971) suggests that laws, educational campaigns, and trash facilities have little impact on littering. And al these studies focused directly on the problem--littering and litter.

Alternatives to the Cross-Sectional Surve

Alternative measurement strategies: 1. self report--diaries.--Diary studies can provide information on "why a behavio is occurring" if respondents describe wh they did what they did. For example, wh boaters choose among streams in an area and locate their movement on a map, the investigator may want to know why they made their decisions. Reasons may inclu "this way was shorter", "too many people the other way", etc. This approach however, has all the weaknesses describe in use of diaries to answer descriptive questions.

Alternative measurement strategies: . participant observation.--Participant bservation can answer the question of why a behavior occurs" both from the oint of view of the observer, who may ngage in the event and record his own eactions to it, and from the perspective f those he observes; the observer inter-cts with them and is often able to learn why" through conversation. Measurement f "why" with participant observation rocedures is most useful in the early tages of a study; it can help the re-earcher ask the right questions later n. Participant observation is often ecessary for a good attitude survey. t should be noted, however, that al-hough participant observation may be ecessary for an attitude study, it is ot a sufficient replacement for such a tudy. Participant observation pro-ides hypothesis, but only the carefully onducted attitude study, with its sys-ematic sample and rigorous measurement, rovides strong support for hypotheses ealing with social-psychological xplanations of "why".

Alternative research designs: longitudinal design.--When the in-estigator wishes to determine if the easons "why an event is happening" hange over time, then a longitudinal esign may be appropriate. This is a articularly useful approach when com-ined with a survey aimed at determining ocial-psychological reasons.

Alternative research designs: experimental design.--If the factors ontrolling a behavior are situational, xperimental analysis can yield data bout "why it is happening". For example, se of campsites along a river may be re-ated to access, visibility, proximity to ther sites, etc. Experiments can isolate he relative impacts of the various actors.

Experimental analysis is the only ethod that allows the researcher to de-ermine directly "how a behavior can be odified or maintained". Although simple bservation of behavior and cognitive xplanations of why it occurs may provide nsight into possible control procedures, y testing of effectiveness of controls nplies an experiment. Research on lit-r control in recreation is an example how experimental analysis can be used to determine effective control procedures (Clark 1976, Clark *et al.* 1972a, Heberlein 1971). A carefully conducted experiment is the key to determining the effective-ness of management actions because the relative impacts of each approach can be clearly substantiated.

RELATED ISSUES

I have discussed a variety of re-search designs and measurement strategies and have presented a simple framework for determining which may be appropriate for providing information about several ques-tions concerning recreation behavior. The decisions that must be made about appropri-ate strategies are more complex than the framework implies. In this section, several important issues that the investi-gator should consider in designing a study are discussed.

A Variety of Procedures Is Necessary

When used alone, none of the stra-tegies described can produce data to di-rectly answer the five basic questions about recreation behavior. Consequently, researchers interested in all the ques-tions must be able to use a variety of research designs and data-collection strategies to get the best results.

Rarely will one of the five questions be studied alone. Usually, a study will combine several. This makes it particu-larly important for the researcher to understand the limitations of the alterna-tive procedures and to select the appro-priate combination to satisfy the study objectives.

Strategy Depends on State-of-the-Art

The appropriate research strategy may depend on what is known about the events of interest to the researcher or manager. Studying a phenomenon about which little is known may require a different approach than if specific variables have been identified.

Participant observation is particu-larly useful in early stages of an inves-tigation and can be used to focus data on four of the five basic questions. More information is required to use the other strategies; systematic observation re-

quires identification and definition of important variables; self reports require the right questions for pertinent responses; and experimental analysis requires identification of target behaviors and possible controls.

An effective overall approach is to focus initial data collection efforts on participant observation to identify variables that can be more accurately measured by systematic procedures. By considering what is known and which of the five basic questions should be studied, the researcher can determine the most appropriate research strategy.

Practical vs. Scientific Importance

An important concern, particularly to data users, is whether the information to be collected will have any practical importance. Consequently, both the researcher and practitioner must understand the implications that the data collection strategy has for potential application. Does the researcher want to study questions of most importance to the manager? If so, the choice of strategies is limited to those best suited to producing valid and reliable data that will directly answer questions of interest.

CONCLUSION: THE EMPHASIS NEEDS TO BE CHANGED

Attitude studies (primarily cross-sectional surveys), if done carefully, can play an important role in answering major questions about recreation and recreationists. They are particularly useful in explaining why certain events are observed. They also give the most systematic information about what people say they prefer (although experiments may give a wider range of choice and tell more about what people actually prefer in certain settings). Attitude studies, however, seem to be done to the exclusion of both observational studies and experiments. Such a strong reliance on these techniques limits the ability to increase our knowledge about a variety of recreational phenomena.

There are several possible explanations for the strong reliance on cross-sectional surveys. First, many investigators incorrectly feel they have a good idea about what is actually happening when beginning a study. Hence, there is a tendency to neglect the basic descriptive questions and move to research that will explain the phenomena. Or investigators may inappropriately think that the behavior-recall data from survey methods will adequately describe what is happening and who is involved.

Another important reason why many investigators focus on attitude surveys is that they believe attitude studies really tell how behavior can be changed. I strongly disagree with this. It is experimental analysis focusing directly on behavior (or attitudes if that is what one wants to change) that can do this. This problem, coupled with the poor relation between attitudes and specific behavior, indicates that more time should be spent in direct observation of or experimentation with the behaviors in question.

Finally, most social scientists conducting research on recreation are trained in survey methodology and often are not familiar with other alternatives. Consequently, this strategy is often used when other procedures would be more appropriate. All recreation researchers, regardless of academic background, need a thorough understanding of the alternative procedures available to them.

Regardless of the reasons, it seems clear that social science efforts in studying recreation, regardless of the setting, need to be refocused. The consequences of not doing so are great, particularly when the data have policy implications. Determining the best strategy for collecting data depends on a variety of factors discussed in this paper. Individual researchers need a basic understanding of *all* the strengths and weaknesses of each strategy.

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ANAGING RIVER RECREATION USE

MANAGEMENT RESPONSE TO GROWING PRESSURES IN WESTERN WHITE-WATER RIVERS — THE ART OF THE POSSIBLE

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ABSTRACT.--Describes agency responses to the increasing demand for white-water recreation, development of management plans, and why planning and public involvement are needed. An example of conflicting interests and resulting political pressure is given.

In the late 1960's and early 1970's, boating use on western white-water rivers began to grow very rapidly. Use on the Colorado River in Grand Canyon in 1972 alone was more than had occurred in the 100 years from 1870 (Powell Expedition) to 1969. Use on the Green and Colorado Rivers in Utah, Colorado, and Wyoming increased similarly. For example, use on Desolation-Gray Canyon of the Green River in Utah in 1975 was more than six times the amount in 1971. Boating use on the Rogue has more than doubled since 1973. The Middle Fork and Main Salmon Rivers, and Snake in Idaho; the John Day and Deschutes in Oregon; the Stanislaus, Tuolomne, and Merced in California were all undergoing the same dramatic increases.

The basic reasons for these increases were: (1) River running was simply undergoing a rapid growth in popularity similar to the growth in downhill skiing of the 1960's; (2) As limits began to be placed on use of the better known and more popular rivers, commercial and private runners began looking around for and using other less well known and less popular rivers; (3) As more and more people acquired the skill to run wild rivers, more boatmen began to respond to growing demand by starting new companies of their own; and (4) River equipment in the past few years has become more available.

As these use pressures grew, public managers were seeing problems develop at the same time. Trash, litter, and human was were accumulating along beaches and camp areas. Trails to various attraction sit began to proliferate. Firewood at popula beach areas became depleted; live trees, brush, and standing, picturesque, gnarle dead trees were being cut for the campfi Beaches and campsites became blackened b charcoal and ashes. Fires along beaches a river bottoms increased. Crowding at att tions, major rapids, and campsites becam problems and people started filing compla about too many other people. Safety bec a problem both on the water and on the beaches. Historic and archaeologic reso were lost.

There are three phases in agencies' responses to these problems. The first i a decision to take action, after they loo for direction, search for authorities, an recognize their limitations and possible dependence upon others. Second is the fo mulation of an operational plan--often af the fact. The plan is affected by publi input, funding, research needs, and manpo allocations. Third, the plan will be tes in a crucible of public opinion, pressur groups, and the power of representative government.

Once we accept the fact that river man- ment will for the foreseeable future re- to quantifiable problems rather than ential ones, we will spend less time cri- izing the decisions made by "management lorers" and look toward a contemporary hodology for the solution of white-water emmas based upon the present situation.

If we cannot--and it seems we cannot-- pete for dollars and man-years needed to n, program, and budget future river prob- s, how can we escape falling into the e traps time after time, given the cer- nty that the problem will be there before plan?

An action plan unfortunately begins with udding problem and the following condi- ns that vary remarkably little between ers: (1) Quite without warning that beau- ul stretch of water is host to a remark- e array of boating equipment and people has sustained some environmental deter- ation--it doesn't look "nice" anymore; The opportunity to implement nonregu- ing alternatives is past; (3) Government ncies with river-related responsibilities l disagree about the need for positive ion, depending on their enabling legis- ion or mandate, usually--but not always-- ng Federal-State lines; and (4) there will one or more organized vociferous groups to battle management decisions, and many illary special interests.

Happy is the manager responsible for a navigable white-water river in a remote a predominately in one ownership with no e than 28 active commercial outfitters. those less fortunate, we recommend a ategy and response designed to avoid tain pitfalls and an early retirement.

ACTION TO TAKE

First, examine the land ownership pat- n through which your river flows, includ- political subdivisions. How many (1) eral agencies are involved? (2) adminis- tive subdivisions (districts, forests, as) within any one agency? (3) States State agencies? (4) counties? (5) In- n reservations? or (6) private lands?

The manager must identify those au- rized to control put-in and take-out nts as well as camping locations. The ager must know if the river has been declared to be navigable, and if so, by whom. If this question is not settled, it must be faced squarely during the discussion of management agreements. What State agency regulates boat licensing and safety; operator licensing and game laws? Are the Coast Guard, Corps of Engineers, or U.S. Fish and Wildlife Service involved?

He must not underestimate the great importance of considering the river's proximity to population centers. Local interests are potentially antipodal to regional and national interests. The manager must weigh the local sentiment about his program if he is to avoid almost certain conflict. Sometimes, unfortunately, conflict is unavoidable.

A conscious effort must be made to define and evaluate authorities exercised by your agency and all others. Are there agencies with seemingly conflicting directions; i.e., mineral and mining development; large irrigation districts; high density recreation? Must you rely on others for enforcing regulations?

Not to be overlooked are the political realities. Who are the congressional delegations and State representatives? If the power structures are understood at the beginning, a more realistic assessment may be made of the programs attainable as opposed to those desirable.

When the initiating manager is aware of the number and orientation of agencies with direct and immediate responsibilities on *his* river, the next step is to describe the problem and need for action to his immediate supervisor and to the highest ranking field official, or officials, within his organization who are responsible for the entire river segment. The report must include operation recommendations to the field official regarding the next steps to be taken. When accepted, the plan should not return to the operational level until workable agreements or acceptable compromises have been reached with all agencies at the highest field level--it usually proves fruitless for one agency to attempt regulation without the cooperation of all.

We do not mean to say that a detailed program must now have complete agreement. That may never happen. The agreement must, however, concern the *need* to take action, any action, now, and the rationale must at least

be understood by all involved. This in itself is probably the biggest job of all.

The concerned agencies must decide, at the highest level possible, upon a management arrangement to administer a river program. Will a lead agency be named to plan and implement regulations, or will Federal and State agencies name members to an interagency managing group? For obvious reasons, the lead agency approach is the best. If an interagency management team must be formed, the fewer the members the better.

A written cooperative agreement may issue, or simply an agreement to agree. Whatever happens, all must propose a beginning action--a study, draft regulations, moratorium on use, or a combination, or whatever; a journey of a thousand miles begins with the first step.

The major point to be made is that top level agreement or understanding must be reached by all responsible bodies before serious steps are considered to regulate use. The natural reaction for a manager is to take those actions within his authority and then request assistance from others.

DEVELOPING AN OPERATIONAL PLAN

Once the administrative machinery is properly balanced and functioning well, we can begin developing an operational plan based upon clearly understood goals and objectives. To bridge the gap between general concepts and identifiable, measurable results, standards must be set up for each objective that can be measured and analyzed.

In the past, agencies have not always been able to respond to the river-running craze with an orderly step-by-step program. The following discussion describes the experiences of a manager with experience at Grand Canyon and areas in Utah.

Many land managers responded to visitor use pressure problems in a strikingly similar manner. This was before the Interagency Whitewater Committee was set up. Their basic response was to: (1) set up interim limits and requirements, (2) initiate research and study programs, (3) gather public input, (4) develop more complete management plans on the basis of number two and three within the basic authority granted by Congress to the managing agency for a specific river or river segment.

Most managers did not have basic dat from which sound decisions could be made. It is generally recognized that there are three major limiting factors that form a basis for carrying capacity determination in river running: (1) *Physical capacity*--actual numbers of people that can be physically accommodated at launch sites, campgrounds, etc.; (2) *Sociological capacity*--the number of people that can be on a riv at any one time without interacting to th point of degrading each other's experienc and (3) *Ecological capacity*--the number o people that a river system can accommodat without impairment to components of the various indigenous ecosystems.

Most interim management plans, while having some differences, have included th following:

A. *Use Limitations*

(1) An overall limit of use, either numbers of people, number of par (groups), or passenger days. (P senger day is one person for one or any part of a day.) Most ove use limits have been based on a cent actual use figure for the g river segment. In essence, use allocation were frozen at the ex ing level at the time limits and related management requirements established.

(2) Allocation of use between user g i.e., between commercial and non mercial, and on one or two river third category of educational al ments was added.

(3) Maximum group size per trip.

(4) Maximum number of days per trip.

(5) A limit on the number of people trips launched per day.

B. *Resource Protection and Sanitation*

(1) Use of portable toilets or installation of permanent toilets at campsites.

(2) Litter and trash prevention requirements.

(3) Use of fire pans for open fires charcoal. Fires are built on me

containers and charcoal is carried out or put in main current of river and pulverized by the hydraulic action of the water. Fires prohibited in certain areas.

(4) Prohibited camping and/or hiking in certain environmentally sensitive areas.

(5) Collection of archaeological or historical artifacts prohibited.

Safety Procedures and Equipment

(1) Life jacket requirements.

(2) First aid kits.

(3) Emergency signaling or communications.

(4) Extra oars or motor.

(5) Boat repair kits.

(6) Pumps for inflatables.

(7) Maps or guide books.

(8) Watercraft type and capacities.

Boatman Qualifications (Commercial Guide or Private Trip Leader)

(1) Minimum experience with similar boat or comparable river.

(2) First aid training.

(3) Boating safety training or certification--State or Coast Guard.

(4) Interpretive skills.

Other Miscellaneous Requirements

(1) Insurance coverage (commercial).

(2) Equal employment opportunity (commercial).

(3) Permit or franchise fees (commercial).

Immediately following the implementation management schemes, most managers began working on studies, research, and inventories. These efforts have been aimed at developing data for resolving social and ecological impacts.

Many land managers have already spent considerable money doing research and gathering other data. At Grand Canyon, during the past 4 years, about 500,000 dollars have been spent on such studies. These initial studies are nearing completion and are currently summarized and reviewed for use by managers in making decisions for future use and management.

As a result (at least partly) of the National Environmental Policy Act, Federal agencies have in the last decade been going to the public for review of changes in management direction. This is especially so of the National Park Service, Bureau of Land Management, and the USDA Forest Service.

Public involvement in river management policies is a sign of the times. We have to have review prior to decisionmaking if we ever hope to make decisions that will be accepted by the river-running public.

Grand Canyon personnel spent a considerable amount of time and effort gathering public input through meetings at various major western cities and such things as questionnaires and workbook response to management proposals.

Most managers in the situation we have outlined have generally been looking at the research and study programs in combination with public involvement and legislative authority as a means to a "Final Management Plan."

As Grand Canyon managers began the management plan effort, it became evident that they would *never* reach a final management plan. Public demand for river trips is dynamic. Some of the research and studies will continue and likely will turn up new data. As new information becomes available and public demands change, managers will have to respond with dynamic plans that adapt to changing conditions and pressure. No management plan can be of value if it is "set in concrete." Grand Canyon is currently involved in a court suit because demands have apparently changed and management has not kept up with that change.

Very few managers have completed management plans as described above. Most man-

agement schemes are so new that research data and public input processes have not been completed as yet.

Why We Need Planning and Public Involvement

When the plan is ready for implementation, whether interim or highly sophisticated, it will be tested in the crucible of the real world. Following is the reaction to an administrative response that relates to a small portion of the Colorado River flowing through one of our great National Parks. We do not suggest that the discussion is definitive but merely an observation of how administrative problems, together with attendant response, occur and the different pressures they engender, especially the political.

In 1971, it became apparent that river use was growing at a tremendous rate, and that riparian ecosystems were being placed in stress due to this increase. Alarmed at this and developing adverse situations on similar white-water elsewhere, managers took initial steps to stabilize use and limit commercial outfitter operations until answers could be obtained for the following:

A. What is the carrying capacity for Cataract Canyon?

B. What is the assessment of impact on vegetation and wildlife?

C. What impact is acceptable?

The initial response to allow growth to 10,000 visitors annually was based upon admittedly meager data and what was "felt" to be acceptable and reasonable, under these circumstances. However, continued development in other areas with similar problems indicated that what had been reasonable might be, in fact, too much for the system. As a result, the second response reduced the 10,000 allocation to 6,600.

On December 9, 1972, a meeting was held and attended by 13 of the 18 commercial outfitters involved to discuss the proposed restrictions. The decision to reduce limits was received as being in the interest of the Park and its environment and, as such, in the general interest of the outfitter, although placing a "lid" on growth. Equal allocations were then made among the 18 outfitters with a withdrawal of 333 for private use. Subsequent to this decision and its review, one outfitter received an additional 333 allocation, in that his operation would have suffered a reduction. This was not intended.

The action to limit use was quite simply an interim management response to use pressures and designed to protect the interest of the Park and its environment until results of scientific study now underway can be completed and incorporated into further management decisions.

To do less would place management in question, and quite possibly be a breach of the Enabling Act of 1916--to provide for use but not to preserve, one outweighing the other. And then came the reaction.

There is nothing like a joint resolution from a State legislative body to make one [illegible] the variables that underline a decision made by the "Little Bureaucrat" as he proceeds to make a "best judgment" decision in the national interest. Visions of expediency transfers (in the Government's interest), clothing and feeding of one's family, career, etc., flash before many eyes as "The Manager" goes about the decision process within a very real political arena.

"A joint resolution of the 40th Legislature of the State of Utah memoralizing the Secretary of the Interior, the Director of the National Park Service, the Superintendent of Grand Canyon National Park, the Superintendent of Canyon-Lands National Park, the Superintendent of Dinosaur National Monument, and the Congress of the United States to protect and promote proper tourism and preservation of the natural wonders of our waterways in the National Parks and Monuments.

Be it resolved by the Legislature of the State of Utah:

WHEREAS, the majority of the river-running companies of Southern Utah are a decided asset to the environment and the economy of the State of Utah; and

WHEREAS, the river-running companies headquartered in the Kane County area are aiding the local economy by hiring over 70 people; and

WHEREAS, Kane and Garfield Counties are economically depressed areas with over 14 percent unemployed; and

WHEREAS, *there is apparent bureaucratic red-tape and discrimination against these river-runners to the extent that they may be forced out of total operation*; and

WHEREAS, these companies are totally committed to a clean, humanly sterile environment in the wilderness areas they visit, leaving behind them absolutely nothing but their footprints; and

WHEREAS, these companies are being forced to submit to severe reductions in patrons; (...ad infinitum...)"

When documents such as these are placed ithin his "in" basket, I am sure "value ystems," "user perceptions," "Recreation nvasion Displacement and Succession Models," ace through the manager's head and are on e tip of his tongue as he begins to defend decision he sometimes wishes he had never ade.

Everyone wants to help; many have sugestions and seemingly gloat:

y good friend called this morning, asking I knew anything about the political clout at...might be able to muster...He explained e problem that you may confront as a result the river traffic cutback.

e may raise some hell with Senator _______. e have another senator on our side, however. He is interested in the river--very terested. So I suggest that if...does try give you a bad time, why don't you write our senator. He's a good friend of mine. I can help you on that score, don't hesitate to call on me.

Sincerely,"

Some deal with "Big Bureaucrats," not eally wanting to assess the situation fully r be confused with facts--only to support friend or special interest:

eputy Assistant Secretary
ashington, D.C.

ear ________:

would deeply appreciate it if you would, an urgent matter, look into what appears be a very serious question of unfair eatment by someone in the Park Service... one of the Nation's leading river guides d spokesmen...

It appears clearly an arbitrary and capricious action, but the result will be to put...a small company out of business.

Sincerely,"

Some individuals go within the agency to attack a decision. The battle can reach grand proportions.

"Dear ________:

Thanks for your letter of November 15th. I am sorry that I have been remiss in getting back to you.

I was amazed with the response that you received after informing the National Park Service that you, one of our most conscientious concessionaires, would not be operating in the Park next year. I was embarrassed by the negative tone of that letter and certainly hope that it is not indicative of strained relationships.

Note: My brief acquaintance with...leads me to believe that they are not merely squeaky wheels. They are very professional in their approach to doing business, and I am not sure that they are being given a fair shake."

You can imagine the joy and good will experienced by the "manager-administrator" after he reviews this note, issued from on high.

Meanwhile, threats have been shrugged off and the "keeper of the national trust" continues, believe it or not, to hold ground.

"In a letter to a protesting outfitter, a steadfast manager explained that the current regulations were in force, pending completion of carrying capacity studies. He further explained that when the studies are complete, he would meet with the outfitters concerning what is best for the environment, the park, and its visitors. The manager reminded the outfitter that he intended to develop a long-range management plan, in cooperation with the outfitters, based upon sound, unbiased, scientific data.

The managing official also assured the outfitter that he agreed with his state-

ment recommending that both sides look seriously at the facts rather than listen to untrue statements. In closing, the manager again reminded the outfitter that he had been going out of his way to keep the outfitters informed of what he did or intended to do, and had solicited their ideas on all phases of the river running operation.

Sincerely yours,

Superintendent"

That being the case, start all over again:

A concurrent resolution of the 41st Legislature of the State of Utah.

"The Governor concurring therein, memorializing the Secretary of the Interior, the Director of the National Park Service, the Director...and the Congress of the United States to protect and promote proper tourism while preserving the natural wonders of our waterways in the National Parks and Momuments by insuring that any regulations of these United States agencies governing the use, equipment, or registration of vessels and motorboats upon the waters within the territorial limits of Utah and other western States be maintained in conformity with State laws and regulations and regulations of the United States Coast Guard and that no efforts be made by those agencies to reduce or restrict the numbers of visitors upon those waters so long as ecological and environmental values therein may be maintained.

Be it resolved by the Legislature of the State of Utah, the Governor concurring therein:

...that we call upon the aforementioned agencies and individuals to reconsider adopted and proposed reductions in numbers of visitors permitted access to white-water trips and to allow normal increases in visitation unless and until evidence based on objective studies reveals that increased usage will cause harm to the public lands through which the rivers flow, so that the ultimate enjoyment of the parks can be achieved with the minimum amount of ecological imbalance, if any...(ad infinitum)..."

How do we, as managers with great regulatory powers over a vast national trust whose management is dependent upon sound thinking and judgment, get into such predicaments when only following orders?

By letter of December 5, 1971, the Director, Office of Management and Budget, asked the Secretary of the Interior to have prepared a study report on "Rationing use of existing Federal park and recreation areas and facilities."

Earlier in 1971, Secretary Morton had written, in a June 17 memorandum to the Director, National Park Service:

"The Public Land Law Review Commission Report has recommended that the National Park service ration the use of certain national parks and wilderness areas in order not to compromise the experience of the visitor...I would like to see this attempted, accompanied by sufficient advance notice to the visitor as to what we are trying to do and why."

The March 1972 task force reports of the Conservation Foundation on National Parks for the Future contain recommendations such as the following:

"High priority should be given to research directed at finding the physical, ecological, and sociological carrying capacity of every unit under the jurisdiction of the National Park Service. This information should be the basis for establishing and enforcement of user quotas to prevent visitation from exceeding the carrying capacity of the environment."

Most of us have repeatedly stated that it is our practice to prepare and maintain a master plan to guide use, development, interpretation, and preservation.

We have also realized for years that to "promote and regulate" appropriate use in accordance with the mandates of the Congress requires for the most part a variety of related services which satisfy the subsistence and accommodation of the public. The important considerations are that appropriate use requires the service, and that geographic or other factors require that the service be provided within rather than outside the agency/area boundaries.

However, to do this adequately, to identify essential services and where they will be provided, requires a plan without bias, prepared in the absence of political, as well as environmental, pressure. *We may say* that it has been our practice to prepare and maintain plans to guide the use and preservation of each area; however, it remains, in fact, that we were without suitable planning in the past and are without suitable planning for a future which has incorporated adequate meaningful public involvement--people do not know what we're doing or why! It's that simple.

The administrative situation that we have just described is not atypical. It has occurred at Everglades, Yosemite, Yellowstone, Cape Hatteras, Bureau of Land Management, USDA Forest Service, etc. The commonality of this experience is that rather than systematically identifying problems and arranging for data to assess, support, or develop a decision, we must first be burned. Then we respond and continue to be burned.

The data that we obtain hopefully will have been collected in a professional manner, presented without academic jargon, concise, and in such manner as will be understood by all, particularly the manager. We do not expect research to make the decision--only provide facts upon which to make it. In this manner, we will move from sheer stopgap tactics to a well defined strategy for management that is politically, legally, and morally sound. One that is understood and can be defended in rational terms.

Public workshops with data collected based upon values and concerns consistent with existing constraints are our only hope--the public *must understand.*

Their representatives must understand that what we do, we have been asked to do by the citizen through his representative.

EXPERIENCES IN MANAGING RIVER RECREATION AND RIVER USE IN MICHIGAN

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ABSTRACT.--Presents a history and analysis of Michigan's attempt to control river recreational use for resource protection and reduction of conflicts by regulating numbers and conduct of canoe users on its rivers by utilizing State Rules and Regulations. Michigan's Natural Rivers Act, the program implementing the law, problems encountered, analysis of progress, and suggestions for more effective river and associated land-use management are also reviewed.

MICHIGAN'S NATURAL RIVERS PROGRAM

Michigan's Natural Rivers Act was launched by overwhelming endorsement of both houses of the legislature and was signed into law by Governor Milliken in 1970. It was passed in response to the public outcry over the misuse of our public waters and their frontages. The Natural Rivers Act provides a system for preserving and enhancing the water quality and flood plains, and the ecologic, historic, scenic, fisheries, wildlife and general recreational values of Michigan streams. It seeks to preserve for the frontage owner, the stream user, and generations yet to come those qualities that initially attracted people to the rivers.

Armed with the Natural Rivers Act and prodded by impatient conservationists (who hoped to designate every river in the State by a wave of the wand), our two natural rivers specialists marched bravely, if hesitantly, into battle.

RIVER SELECTION

Three rivers were selected as pilot rivers for the Natural Rivers Program and the identification of the outstanding streams of the State was begun. Next 10 rivers were selected from each of the three broad regions of the State (Upper Peninsula, Upper Lower Peninsula, and the Lower Peninsula below the Bay City-Muskegon line) for study. This provided a diversity of rivers, from remote to near urban in terms of accessibility, and provided protection to outstanding streams throughout the State (fig. 1). The selection process involved recommendations from DNR's own field staff, outdoor writers, conservation clubs, soil conservation service, and other groups or organizations interested in river quality and preservation. This was probably the first test of public involvement. The intuitive knowledge of these informed contributors could not have been improved upon by a $500,000 "scientific" study. The 30 rivers selected, have approximately 6,000 miles of river eligible for designation.

So far 6 rivers have been designated as natural rivers by the Natural Resources Commission and work is in various stages on 13 others. As a river is designated or as local interest develops, additional rivers will be added to the study group.

EARLY PLANNING EFFORTS

The Natural Rivers Act requires a long range comprehensive plan for a selected river upon which local zoning or State zoning rules can be based. Plans for the first two rivers to be studied were developed largely by DNR

Figure 1.--*Michigan's Natural River System.*

staff in cooperation with a functional river watershed council, or a local planning commission. Citizen involvement was virtually absent, much to our later regret. A degree of grudging agreement was reached by participants in the planning process in each case, and was quickly met with the wrath and indignation of frontage owners at the public hearings. It became obvious that plans for other people's properties could not be made without some effort toward public education and involvement.

THE EVOLUTION OF PUBLIC INVOLVEMENT

Taking the cue from our success in identifying the prime candidate rivers for preservation and benefiting from a 2-month sabbatical in Europe, where I was exposed to the "Plannungs Gruppe" approach used in West Germany, the natural rivers staff initiated an innovative step of directly involving property owners, local public officials, knowledgeable local technicians (such as planners, health officers, soil conservationists, etc.) and other interested citizens as coequals and partners in developing river plans for recommendation to the Natural Resources Commission. Thus, we applied the "Mitbestimmung" or codetermination of West German labor-management decisions (which has been astoundingly successful) to the natural rivers planning of the DNR.

We must recognize, however, that we benefited from a peculiarity of the times. As the Wall Street Journal on October 16, 1972, reported:

> "From New England to the west coast, the average taxpayers, the men and women who make the economy and the country tick, were backing away from the plans and programs, the causes and crusades that they had enthusiastically jumped into in recent years. Possessed by almost a quiet desperation, residents of America were disregarding the larger issues and turning inward. They were and largely still are, frustrated with institutions--from the top of the federal government on down. They have learned from some very real experiences. They have come to understand that the institutions are running things, and that they're beyond the control of individuals. So people are just giving up. They are directing all their efforts toward influencing the things that, rightly or wrongly, they think they can control."

Thus, the "problem" of preoccupation with one's own back yard, or one's own thing--became the "opportunity" for the Natural Rivers Program. In the past few years, the natural rivers staff has vigorously promoted a policy of informing as many citizens, organizations, and governmental bodies as possible before beginning natural river planning. This is accompli[shed] by contacting community leaders, the coun[ty] extension agents, field personnel, sportsmen's clubs, watershed councils, soil conservation districts, and any other organizations that might be interested in the program and having them arrange meetings at which to present the program.

THE CITIZEN PLANNING GROUP

When it appears that acceptance or at least some support of the program has been attained, representatives of organizations, governmental units and property owners are asked to be a part of a "Planning Group" responsible for developing the natural river plan. In this atmosphere of give and take, grass-roots planning and direct involvement, it is usually possible to devel[op] a mutually acceptable natural river plan. The commitment in time, infinite patience, perseverance and tolerance cannot be underestimated. Frustrating as it is, citizen groups and local governments are careful about detail and cautious in making decisi[ons]. Decisions regarding portions of river to b[e] designated, setback requirements for new homes or structures along the river, depth and type of management of a natural vegetation strip, minimum lot widths, industrial and commercial setbacks, septic system requirements, earth moving and disturbance requirements, size of boat docks, stream channel stabilization requirements, litter enforcement, and canoe and motorboating controls are long in coming. But after the property owners champion a setback of only 25 feet, and the environmentalists advocate 300 feet, much discussion, sometimes heated debate and even threats of physical abuse follow. Then votes are taken on motions for 25 feet and 300 feet, both of which fail. After several more votes and amendments, a setback of 150 feet finally passes, and nobody is happy. But that is democracy, and the process, hopefully, leaves the participants more enlightened. One often reflects

ıat it would be much faster to arbitrarily :velop a plan within staff, but the result ›uld be only to add to the already burgeon-ıg shelves of solid waste matter that line ır planning offices waiting to be recycled. ır activities are governed by the old :overbs: "Without knowledge even zeal is ›t good"--and "he who acts hastily, blunders".

Even though the "Planning Group" method s a slow process, Michigan leads the Lake entral Region in miles of river protected ıder State Natural Rivers Programs. This ıccess in spite of the fact that we have much smaller budget than most other States.

Efforts of this type are not without ıeir ups and downs. For instance, it is ›mewhat unnerving to have a burly property vner poke his finger in your chest with ıe words "You're not bullet proof, Buddy". ›wever, there are also times of reward when ›meone steps forward at public hearings to ay "What use is a home on a river when the iver is an open, muddy sewer, with buildings ıoulder-to-shoulder along its banks? Zoning s an accepted thing in cities. It is ›mmonly understood that in order not to estroy the neighborhoods, folks cannot do lot of things with their property. It is ime we gave the same consideration to our ivers and lakes".

LAND-USE CONTROLS

Michigan is emphasizing land-use controls long streams because we feel strongly that lthough nonconsumptive uses such as heavy anoe and fishing pressure may injure streams emporarily (as did the logging runs in days ast), it is much more critical to control tream bank development. Once a home is uilt along a stream bank, it becomes a ixture for generations, and often is the eason for other stream bank changes such s erosion control structures, bulkheads, ocks, etc. A few years ago, the Bureau of port Fisheries and Wildlife retained the allup Poll organization to find where eople would like to live for a quality ife if they had a choice. Only 15 percent anted to live in the cities. Eighty-five ercent would rather live on the farm, ural area, small town or area of resource eauty--such as mountains, rivers, seashore, tc. This tells us our troubles are just eginning.

CANOE USE INCREASES

The law which establishes the Michigan Department of Natural Resources also permits it to establish rules to protect the lands and property under its control against wrongful use or occupancy and from depredation or destruction.

As in other States blessed with scenic river resources, the number of canoeists are increasing rapidly in Michigan, for example the number of commercial liveries increased from 165 in 1972 to 226 in 1975. Canoe sales are also up according to some manufacturers in Michigan. One concern quadrupled its production from 1972 to 1974. On one popular river, the Pine, the number of canoe trips increased from 13,000 in 1973 to about 30,000 in 1975.

CONFLICTING USES

Heavy canoe use is conflicting more and more with other river users. Many trout streams are no longer fished during the daytime hours because of canoeing disturbances. This situation suggests the need for users time zoning in the future. According to the U.S. Forest Service, this canoeing pressure has resulted in the deposit of about 20,000 beverage cans and bottles in a 40 mile stretch of the Pine River, Michigan. In addition, noise, drunkenness, rowdyism, trespass, vandalism, and theft are increasing rapidly. Conflicts are common among canoeists and fishermen, sightseers, bird watchers, swimmers, and frontage owners. Serious canoeists who appreciate the esthetics, outdoors, and solitude are offended by the shenanigans of hordes of boisterous social canoeists.

CANOE-USE CONTROLS

Early in 1970, there were virtually no controls or limits on the usage of rivers on any Federal or State land of other States in the United States. Today, 47 rivers or river stretches under Federal or other State jurisdiction in 13 States have controls either on the number of launches on streams, number of liveries that service the streams, or both.[1] Controls of these types are enforced either by the Forest Service, Bureau

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[1]*Paul Rasmussen: Michigan DNR phone and mail survey conducted August 1976.*

of Land Management, National Park Service, or by State or local units of government.

As early as August 1970 the problems and conditions on the Au Sable River were discussed at a Natural Resources Commission meeting and a study proposed. Under the auspices of the Au Sable River Watershed Council, the varied interests in the river from property owners to users to canoe liveries were brought together to come up with a use control program. Although it worked on the river problem until the spring of 1971, the council failed to agree on a solution.

One positive spin-off resulted, however, because the Crawford County Board of Commissioners with the assistance of the Marine Safety Section of the DNR, adopted rules for the Au Sable River in July of 1971. To become effective, the County rules also required the approval of the Natural Resources Commission. After a soul-searching session of the Commission, it directed Department personnel to draft a set of more comprehensive River Use Rules that would encompass not only Crawford County, but the heavily canoed Pine, Pere Marquette, the remainder of the Au Sable and the Manistee rivers as well.

As stated in the paper prepared for the Legislative Service Bureau by the Department of Natural Resources' Paul C. Rasmussen, the rules were designed to serve the following purposes:

1) Protection of the physical resource against abuse and the environmental resource against degradation--now and preventively as to the future. This objective includes protection against streambank degradation, destruction of fish habitat, littering, etc. It includes protection against overuse of rivers which precludes the enjoyment of beautiful, natural, and relatively quiet surroundings or an esthetic environment.
2) Resolution of the conflicts between river-users in the most equitable way:
   a) Canoeists and trout fishermen
   b) "Social canoeists" and "serious canoeists"
   c) Motorboaters and the above types of recreationists
   d) Riparian owners and other river users, especially canoeists
   e) The above type of river-users and future new types of river recreationists.
3) Aid in insuring the safety and enjoyment of all river-users.

Groups such as Trout Unlimited, Michi[gan] Trail Finders Club, the large and influent[ial] Michigan United Conservation Clubs, the pr[es]tigious West Michigan Environmental Action Council, as well as the Lake County and Pine River Property Owners Associations supported the rules. Canoe Livery Associations, which have a direct economic intere[st] were the primary opponents at the public hearings that are required in the rule-making process.

In short, as Rasmussen reported, the rules provided for "limitations on weekend[s] and holidays on the number of watercraft and their time of use during the heavy-use season from the opening of trout season through Labor Day, and by imposing rules of conduct for all river-users during the entire year". Comparable standards applie[d] to all similar stretches of the rivers. Heavily used sectors of each river were divided roughly into stretches that approximate the average day's use by watercraft (4-6 hours), taking into consideration available access points.

Carrying capacities involving such factors as stream width, rate of flow, dept[h] of water, and meanderings or the course of the river, were determined for intensive nonmotor watercraft use by Fisheries Division and other officials in the Department of Natural Resources who work with and are familiar with the rivers.

Field observations showed that a problem was developing on a stretch of the Pine River. The use on that stretch was estimated at about 200 canoes per day on heavy-use days. After much deliberation, a limit of 150 permits per day was set in addition to special watercraft users (such as riparian owners) who would be on the stretch by special permit.

This figure was then applied to a lower but similar stretch on this river and to the other three heavily used rivers considered to be similar in carrying capacit[y]. A lower limit (100) was assigned to stretche[s]

n lower capacity. On the Pine River where re are three successive stretches, the t that many canoes might pass from one etch to another, was accounted for by plying a lower limit to the upstream etch.

In scheduling canoes on a stretch, the tinent factors are point of release and ed of canoeing. Most canoes on these ers float at around 3 miles per hour or ile in 20 minutes. At this rate and as- ing a common beginning or release point, -minute spacing interval, or 30 canoes hour, would be required, to keep canoes ited to 10 per mile.

All watercraft were banned on the head- ers and certain small tributaries of des- ated rivers in order to protect the river and fish habitat. In other words, these etches were so small or of such small rying capacity that they were considered uitable for significant watercraft use more important for fish management.

Motorboating was prohibited on some etches and limited to slow no-wake speeds others in order to avoid conflicts with h canoeists and fishermen.

During the review of the rules by the nt Rules Committee of the House and Senate, rule limiting the hours of canoe use to ween 8:00 a.m. and 6:00 p.m. was elimi- ed. This rule would have left the stream e for trout fishing in the dawn and ning, the peak time for fishing on these mier fishing streams.

Provisions were made to obtain permits the liveries and DNR field offices. ance reservations and certain types of ited exceptions to the permit require- ts for people on the river, camping, or ing along the river were provided for. sonal permits were also available to parians for up to two water craft owned them. Special permits could also be anted for special events and compassionate ses, with discretion to make exceptions to time, type of craft, and areas for tercraft use.

In order to protect against litter, e rules required plastic container bags used for the wastes of river users. In der to ward off river bank erosion and ep usage under control, the rules provided r the use of only designated put-in and ke-out points for watercraft users.

Rules of conduct for all river users were publicized and distributed at liveries to help ward off conflicts between different types of river recreationists and riparian landowners.

Thus by limiting canoe use on the rivers specified, the canoeists would be encouraged to spread over a greater number of rivers and reduce the pressures which are depreciating the select streams.

After the Natural Resources Commission adopted the rules in June of 1972, the Recreational Canoe Association sued to enjoin the State from promulgating the rules. The DNR subsequently agreed not to effect the rules until the legality of the Department authority to establish such rules and the legality of the precedures followed to establish the rules could be tested in court. The court focused upon the Department's rule-making authority because it was a paramount issue.

The Lake County Circuit Court found that the DNR did not have the authority under the law to promulgate such controls. The Attorney General's office in representing the DNR appealed to the Court of Appeals which also ruled against the rules. The ruling implied that courts in other States might make a different decision because of more liberal rules. With this hint and the momentum of past efforts, the Attorney General, acting for the DNR, appealed the decision to the State Supreme Court which heard the case in June of 1976. We are still awaiting its decision.

In the meantime a bill has been introduced which would by legislative act give the DNR specific authority it has been so arduously seeking in order to establish river use rules. Of course, were this bill to become law, it would be limited to controlling problems on heavily used rivers and would not give the DNR authority to make rules on all threatened natural resources. A favorable Supreme Court decision for us on the river use rules, however, would.

In conclusion, Michigan is moving to protect its river resources on two fronts. The Natural Rivers Act of 1970 permits land use controls along the banks of designated streams to regulate docks, structure setbacks, cutting of natural vegetation, and

other uses. Second, River Use Rules promulgated under Department of Natural Resources permissive legislation would regulate numbers of canoeists using certain heavily used streams, but currently are being challenged in court. We are optimistic that the publi right to quality recreation without depreciating the natural resources will prevail.

ALLAGASH WILDERNESS WATERWAY

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ABSTRACT.--Describes problems and solutions and use experience during the first 10 years of management. Problems related to increasing use include establishing public routes of access, registering users, dispersal of users along the route of travel, restricting group sizes, establishing total use limits, and the proper disposal of litter.

The Allagash Wilderness Waterway consists of a 92-mile long corridor in northern Maine, beginning at Telos Dam at the eastern end of Telos Lake, extending northwesterly to Allagash Lake and Allagash Stream, and then northward towards the St. John River and Allagash Village (fig. 1). There are no organized local jurisdictions in the Waterway.

In the early 1960's, the Allagash received national attention because of two reports published by the U.S. Department of the Interior: (1) a "proposed Allagash National Recreation Area" and (2) a "proposed Allagash National Riverway". Both suggested that the area be added to the National Park System.

In 1963, the State of Maine created an "Allagash River Authority", which provided for the creation of an Allagash Advisory Committee to "formulate plans and proposals for preserving the Allagash River Watercourse so that the people of the State and its visitors may be assured of the continued opportunity to enjoy the benefits of the Allagash River Watercourse as a place of natural interests and scenic beauty". As a result, the State Legislature in 1966 passed two acts: the first created the Allagash Wilderness Waterway and appropriated monies for its initial operation and maintenance; the second authorized a $1,500,000 bond issue to acquire lands and waters to encompass the Waterway. The first act allowed for the State acquisition of an inner or "restricted" zone in which camps, timber cutting, and construction of any kind (except for administrative purposes) are prohibited. This zone varies from 400 to 800 feet from the high water mark (average, 500 feet) and contains 22,760 acres of land and approximately 30,000 acres of water. Lands in an outer zone (one mile back from the high water mark) are privately owned but timber harvesting operations based on approved cutting plans by the State are allowed. The outer zone encompasses approximately 150,000 acres.

In July 1970, the Allagash was designated as the first State-administered component of the National Wild and Scenic Rivers Act of 1968. By 1972, all land acquisition was completed. The cost was $3 million, one-half of which was financed by the Federal Bureau of Outdoor Recreation out of the Land and Water Conservation Fund. Except for one minor exception, all landowners sold their land willingly to the State. In 1973, an Allagash Wilderness Waterway Concept Plan was published by the Bureau of Parks and Recreation.

MANAGEMENT PROBLEMS

The Allagash Wilderness Waterway Concept Plan and an Allagash Visitor Use Survey conducted in 1973 addressed the major management problems in the Waterway: establishing public routes of access; registering users; dispersal of canoers and campers; restricting group sizes; establishing total use limits; and proper disposal of litter.

Access

Access into the Allagash Waterway is

Figure 1.--*Map of Allagash Wilderness waterway.*

sible only over two privately controlled vel roads that have been designated by State. The Bureau is negotiating with downers for easements to guarantee that public will always be able to use these roads.

There are possible water access routes ng private roads that are not within the agash Boundaries. The Bureau requires t users entering by these water routes ister with the first ranger they meet or first ranger station they reach. Those ering by float planes have the choice of designated landing sites within the erway and also must register upon arrival.

Registration

Registration was initiated in 1967 imarily to ensure the safety of visitors i their contactability during emergencies. se registrations also provide data for e histories. The Bureau hopes to conduct sitor Use Surveys every 5 years by ex- nding the registration process.

Beginning in 1975, registration fees r overnight users were collected at the ntrol gates operated by the private ndowners on roads leading to the Waterway. ough still in the experimental stage, this ocedure seems to have worked satisfactorily. allows the Allagash rangers to spend a eater percentage of their time on more portant management functions, though they end some time registering parties and llecting fees.

Visitor Dispersal

Dispersal of canoe/camper groups during e peak use months (July and August) from e straight line, linear route of travel, a problem. Such groups are urged to use mpsites located off the normal route of avel, especially large, organized groups. oups led by guides have responded well to is, but dispersal still remains a problem.

Group Size Restrictions

Our 1973 Visitor Use Survey showed that rties of 12 or more persons created a isproportionate impact within the Waterway. ch parties accounted for about six percent the total but accounted for 30 percent the total visitor-nights. Although such rties were primarily fishing and wilderness iented, they created a negative visual impact to the smaller parties both along the watercourse and at the campsite.

As a result, and after a thorough discussion of the alternatives with the Allagash Advisory Committee (a citizens advisory committee), the Bureau restricted party sizes to 12 persons or less beginning in 1975. The only exceptions were granted for parties led by commercial guides serving such a function on the Allagash for the previous three consecutive years. Eventually, as these guides cease to do business in the Allagash, there will be no parties of more than 12 allowed in the Waterway.

Use Limits

The 1973 Visitor Use Survey also disclosed that total use during the peak month of August was reaching a maximum level. An average of 1.1 parties used the 71 designated campsites each night during August of 1973; this assumed that all sites were being used equally. This meant, given the dispersal problem, that each group probably had to share its campsite with at least one other party, a situation that detracts from the wilderness experience.

Again, after a thorough discussion of all of the alternatives with the Allagash Advisory Committee, the following three measures were adopted: (1) group-size restrictions were imposed; (2) Maine publicity agencies were requested not to publicize the Allagash; and (3) a fee system was imposed in 1974. The thinking behind No. 1 was that such parties as scout and church groups would not want to reduce their size and therefore would seek another area for their wilderness trips.

All Maine publicity agencies have cooperated. They have not publicized the Allagash. They only provide information upon request.

The registration fee began as a \$1.00 registration fee in 1974. It was expanded in 1975 to be a \$1.00 per night fee for Maine residents and \$2.00 per night for out-of-State residents. It was purposely started at a low fee in order to get users accustomed to paying a fee.

It is too early to confidently predict the impact these measures have had on total use. Table 1 does provide an indication of the impact.

Table 1.--*Annual visitor totals for the Allagash Wilderness Waterway by parties, individuals, and visitor days 1966-1975*

Year	Parties	Persons	Visitor Days[1]
1966	1,011	4,141	27,008
1967	1,065	4,539	26,831
1968	884	3,786	25,921
1969	1,134	4,820	29,720
1970	1,251	5,460	37,303
1971	1,492	6,345	36,274
1972	1,579	8,260	42,952
1973	1,877	8,337	50,361
1974	1,684	7,477	45,294
1975	2,400	9,477	43,498

[1]A visitor day is the total number of nights, plus one, an individual camps in the area.

Total visitor use increased only 10 percent from 1966 to 1969 but almost 70 percent from 1969 thru 1973. It has decreased almost 14 percent since 1973. The measures taken must have helped, but the national energy problems that began in 1974 were certainly a factor.

Designation of the river, which occurred in July of 1970, may have been responsible for the large increase in use between 1972 and 1973. Publicity of this on maps and in brochures also may have been a factor.

The effect of the group size restriction are most evident. The number of 1975 parties has greatly increased while average party size has decreased and average length of stay has greatly decreased (from 6.04 days in 1973 to 4.61 days in 1975). The decrease in length of stay is most likely attributable to the overnight fee imposed in 1975.

Disposal of Litter

The proper disposal of litter has always been a problem. During the 1960's and early 1970's, users were encouraged to carry-in and carry-out. A trash barrel was also placed at each campsite and users were encouraged to dispose of wastes in campfires.

This procedure never has worked. Use seem inclined to leave wastes in trash barrels, often filling the barrels to over-flowing. Rangers spent a large percentage of their time cleaning campsites and hauli trash. In 1974, again following the discussion of alternatives with the Allagash Advisory Committee, it was agreed that tra barrels should be removed from campsites a located only at the ranger stations and users are encouraged to transport their wastes there. This program seems to be working. A carry-in, carry-out policy is still encouraged.

SUMMARY

State management of the Allagash is n into its tenth year. Total visitor day us has increased 61 percent in those 10 years Number of parties has increased 137 percen number of persons, 128 percent. Winter us has also steadily increased with the adven of the snowmobile for ice fishing and snow-mobiling. A winter use registration progr was begun during the winter of 1975 to 197 it is presently difficult to predict the future winter use of the area until a few years of user statistics have been gathere

If anything has been learned since 1966, it is that managers must be willing to be flexible and must be willing to try different methods towards solving problems Problems that are seemingly hopeless can often be easily solved: a so-called "illegal" water entry point was simply mad legal; a hopeless litter problem was solve (at least temporarily) by removing trash barrels from the campsite.

The Bureau's policy is to update its Visitor Use Survey and its concept plan at least every five years. These efforts, combined with discussions with the Allagas rangers and the Allagash Advisory Committee will usually yield simple, acceptable alter-natives to solving management problems. Th Bureau does not want to be in the position of being a law enforcement agency; it desir to manage the Waterway both for the people and for the protection of the resource.

CANOEING USE OF HURON-CLINTON METROPARK

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ABSTRACT.--An urban regional Metropark system continues to encourage use by canoeists of the Huron and Clinton Rivers. Unrestricted canoeing use has been encouraged by river inventory, canoe maps, clean-up, and canoe rental concessions and facilities. We need to establish different standards for urban rivers than for wild rivers. These standards should include landscaped urban scenes and manufacturing sites as well as natural scenery. Canoeing use should be unrestricted to alleviate social pressures and offer canoeing experiences to urban residents.

The French voyageurs and the Indians villages along the banks are gone, yet the Huron river is teaming with canoes. ...he birch barks, but rather those of ...num, fiberglass, wood and canvas--with ... like Sawyer, Oldtown, and Grumman. ...anoe rental folks have arrived too, ...eet the needs and demands of new river ...s. We are beginning to see developing ...ve affair between people from all walks ...ife--businessmen, students, children, ...retirees--and the Huron and Clinton ...rs because the waters of the river are ...ner than they have been in a long, long ...

HURON-CLINTON METROPOLITAN AUTHORITY

The Huron-Clinton Metropolitan Authority, "Metroparks", created in 1939 by the State ...slature, is a regional park agency cov-...g 5 counties in southeastern Michigan. ...Authority has an income of some $8,000,000 ...ally based on 1/4 mill of the assessed ...ation of property in the five-county ...on surrounding the City of Detroit (fig. ...

The Huron-Clinton Metropolitan Authority ...developed park facilities in the Huron ...Clinton river valleys which encircle ...city of Detroit on the north, west, and ...h (fig. 1). The Authority is dedicated ...providing outdoor recreation for the more ... 4 million people living in southeast Michigan. We learned early that one of the necessary attributes of a regional park must be water--to look at, fish in, swim or boat in. The park facilities if not on water, are located close to it, and range from boat and canoe rentals, swimming pools and ice skating areas, to picnic grounds, cross-country ski areas, and nature centers.

We've asked our land acquisition people, planners, engineers, and natural resource managers to keep in mind that a Metropark must accomodate large numbers of people. For example, in one Metropark of 4,500 acres, annual attendance is about 2 million, or about the same as at Yellowstone National Park with its hundreds of thousands of acres. Regional parks must be so designed that they can accommodate these crowds without limiting attendance or degrading the resource.

Our nature centers and nature areas, comprising about 400 acres, can handle on a sustained basis an annual attendance approaching 100,000 without overcrowding. These areas are not some people's idea of a nature area because the trails are 4 feet wide, avoid steep and treacherous areas, and are relatively short. The point is that many, many people like these facilities and use them throughout the year and may get from them the only opportunity that they will ever have for this type of experience. Annual attendance is generally running about 10 million total for all 10 regional Metroparks.

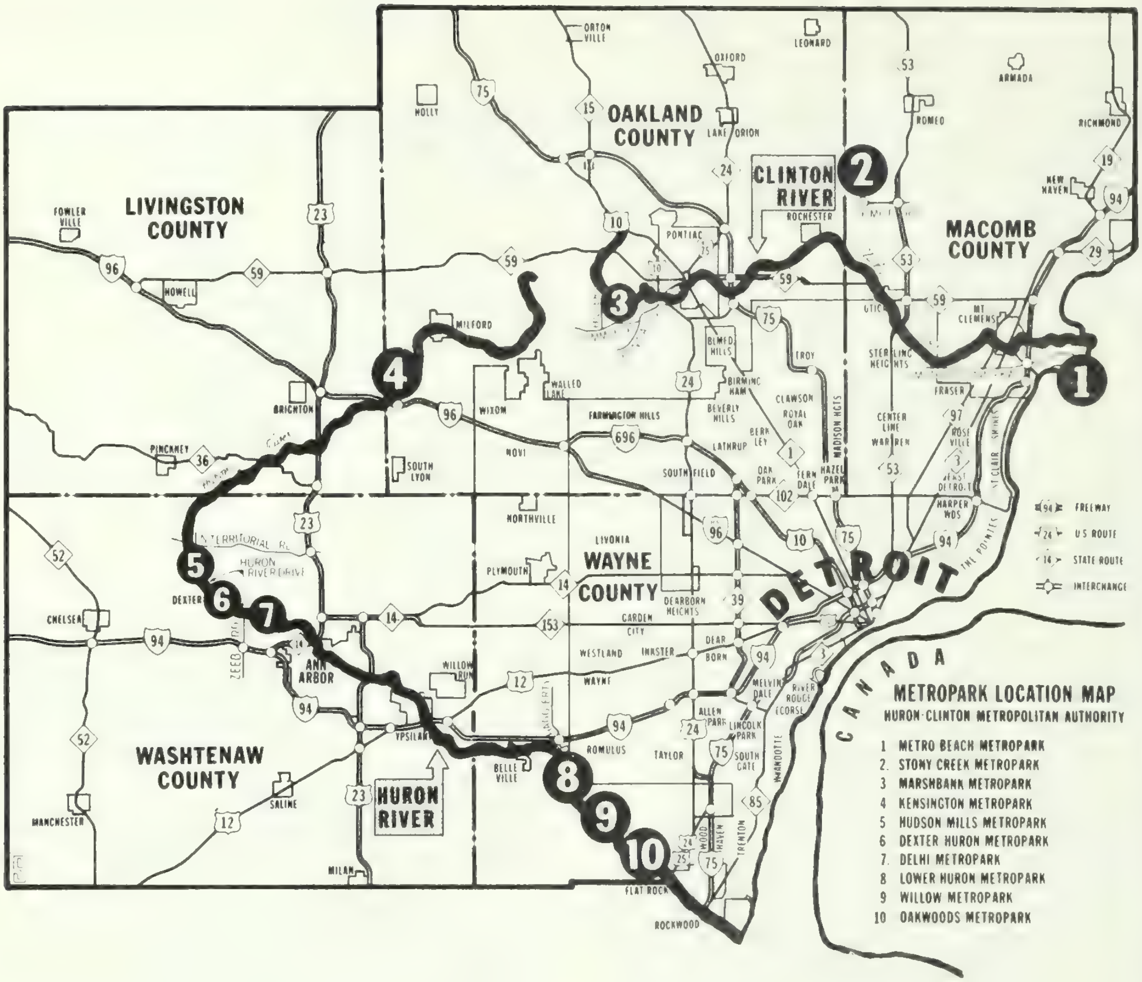

Figure 1.--*Metropark location map also showing Clinton and Huron Rivers.*

DEVELOPMENT OF CANOEING

The Huron River is about 125 miles long and gently flowing except during the spring flood stage. It varies from 6 to 8 feet wide at the headwaters to about 125 feet wide where it empties into Lake Erie. The Clinton River is similar except that it is somewhat shorter and empties into Lake St. Clair above Detroit. Both rivers have a number of natural lakes and a few impoundments create artificial lakes. Most of the year the current is gentle enough that canoeists can paddle upstream, although floating downstream is most popular.

In order to encourage canoeing of th[...] backyard-type rivers located in an urban area, staff people of the Authority have canoed the rivers, keeping track of time and distance, bridges, possible launching sites, portages and other pertinent natura[l] and manmade features such as college campu[s] city, regional and State parks, restroom a[nd] clean-up facilities.

Making the Clinton River canoeable t[ook] much effort because of the Dutch Elm disea[se.] Elm trees are found along flood plains in great numbers, and as they succumbed to th[e] disease, they fell and effectively blocked

linton River. The Authority, several s, and many people working together successful in opening the Clinton River e year from Rochester to the Lake, a nce of some 25 miles (fig. 1). Com- ies through which the Huron and Clinton s flow recognized and were willing to t in developing the recreation poten- .

Two coinciding movements--cleanup of nvironment and the back-to-nature move- -have caused a great upturn in canoeing, o a lesser extent boating, on these s. The leadership of the Michigan tment of Natural Resources, Water Re- es Commission, the river communities, he Federal government in guiding and plishing the cleaning of the Huron and on Rivers has been great. Ten years he rivers were not very attractive due sightly and smelly water. Now the s are relatively clean and as a result epeatedly used. According to canoe l businesses there is a trend toward ning to use the same rental canoes both up and down the river.

There is also increased use by our residents. With improvements in quality, availability of canoes, and ess to cities, every indication is canoeing will continue to increase.

SHOULD CANOEING ON URBAN RIVERS BE UNRESTRICTED?

Contrary to the views of some, I believe a river in an urban setting should be stricted. Properly used, an urban river lo much to alleviate pressures on more e and sensitive river systems. This t to say that there is no need for re- ting, or perhaps prohibiting, use on rivers that are environmentally sensi- or of outstanding quality. We must, er, guard against ill-advised restric- s. One such example is the Au Sable in northern Michigan, a beautiful, , sandy river ideal for canoeing and fishing. Restriction as to canoeing s and numbers was attempted by a special rest trout fishing group. Today. how- , the Au Sable remains open on an un- ricted basis for canoeing.

Unrestricted use of urban rivers also help to alleviate social pressures in crowded urban areas. In many cases these rivers offer the only possibility that city people have to experience canoeing. They should not be denied the right to canoe these rivers because someone feels they are overused by wild river standards. Often a quiet urban river is about all the canoeing experience that they can or wish to handle. People should not be denied the opportunity to canoe because they do not have the time, money, or inclination to travel to the more remote rivers. They too become state repre- sentatives, congressmen, and professors and as such will be voting and directing programs and development.

One of the trends that seems to be emerging on these two urban rivers is greater use by single canoes as contrasted with groups of canoes. More and more we are seeing a 1-canoe party using their own canoe or renting one from a concessionaire. The re- sults seem to be a more quiet experience for the canoeists and less disturbance to others living close to the river. Another trend that the concessionaires report is that single canoe parties are being more selective about when and where to go canoeing. Some of them seek solitude and want to avoid crowds; others want to join crowds and be where the "action" is. Weekdays tend to be quiet, while on weekends there are many people and activities and much heavier use. Some sections of the river also are better adapted for quiet and environmental experi- ences while other sections such as that running through the University of Michigan campus, lends itself more to socializing.

Encouraging Use

Metroparks have taken several positive steps to encourage the unrestricted use of these two rivers by the general public. One of the first was to record the canoeing time and distances between launching and takeout sites, bridges, potential canoe camp sites, and portages. Next came the clearing of the river of fallen trees and other debris, sometimes with our crews and sometimes in cooperation with cities and citizen groups. Other steps that contri- buted a great deal to the use of the river were the establishment of canoe camping sites and the publishing of canoe guides. Currently the Metroparks publish some 15,000 of these guides annually for free distribu- tion to the general public. In spite of this we know very little about who canoes the river, when, and how often. We only know that demand and use is heavy. Perhaps

the dissemination of information through canoe guides has worked against us in that it permits all to use the river without giving us a check on use. Perhaps the studies currently in progress by several universities on the Huron River will clarify and detail this matter.

Another step the Metroparks have taken to encourage use of the river for canoeists is to write concessionaire contracts with canoe rental people. Three such contracts have been written in the past two years and additional ones remain a possibility to encompass sections of the rivers not presently covered. We write news releases at appropriate times to alert the public to these facilities. The news media then follow through with pictures, TV spots, and announcements of special events such as canoe races, etc.

Finally, in my opinion, wild river standards should not be imposed on our urban rivers; we need to encourage urban canoeists, not restrict them. Let our river banks remain open to our urban scei so the canoeist can see the landscapes, t structures, and even the manufacturing plants and railroads for they too are pa of the urban life. Just as we do not pe 20-foot wooden fences along our city str so we should not permit those who would our urban rivers with a 50-foot or wider strip of dense vegetation 60 feet high. we move into the next stage of river use let us plan for variety in our river syst and develop standards for urban scenic rivers to reflect the beauty and creativ ness of man in urban areas. Let us keep restrictions to a minimum as we plan our urban river use.

GETTING YOUR STORY ACROSS — INTERPRETING THE RIVER RESOURCE

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ABSTRACT--Interpretation as it relates to river systems, has special needs. These are discussed in light of the opportunities and problems associated with different sites, audiences, messages, and media. The appropriateness of media to river classifications is emphasized. Examples of interpretive services are used to illustrate the principle points of the discussion.

While most river managers are blessed h an exciting interpretive resource, they also faced with some special interpree needs and problems. Water naturally racts people, thus this provides a great ortunity to further educate them through erpretation. However, safety consideraons, user problems, and competition ween media and the natural magnetism of ers, call for careful interpretive nning.

The mushrooming need for effective erpretation is evidenced in many ways. itors increasingly request information t will help make their river trip more oyable. Not helping a visitor to reciate the resource's vulnerability ng with the special management needs of river results in action that is misded, or no responsible action at all. ufficient training of visitors in safe, fortable, and low-impact use of rivers ns that more of the manager's efforts budgets go instead toward remedying ative impacts. Observations have also wn that a lack of appreciation by itors for the effect of large numbers users on the river resource and on other rs results in antagonism toward regulions and increased vandalism.

Dynamic interpretive programs can nge all this, but it takes careful plang, creative design of media, and effece administration to have a quality prom. Since detailed guidelines for intertive planning and administration can be found in agency handbooks, these are discussed only briefly. The main emphasis of this article is on which media are appropriate for use in river interpretation.

GETTING STARTED

There is an unfortunate tendency for managers to select the medium they want to use before deciding who their target audiences are and what they want to say to them. This has led to some costly mistakes. The "communication spiral", (**fig.** 1) should guide all interpretive planning. Carrying out the steps in the sequence shown will produce an effective communications program.

Audience Analysis

Audience analysis is the first step, and basic to everything that follows. An audience analysis checklist is given in the appendix. A lot of detail is required; but the more that is known about an audience, the better the resulting interpretation.

One item needing close attention is visitor motivations as they relate to the river resource. In a recent study conducted at Dinosaur National Monument, Roggenbuck[1] found that is important to understand the

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[1]*Socio-Psychological Inputs Into Carrying Capacity Assessments for Float-trip Use of White-water Rivers in Dinosaur National Monument. 1975 Unpublished Ph.D. Dissertation, Utah State University, Logan, Utah.*

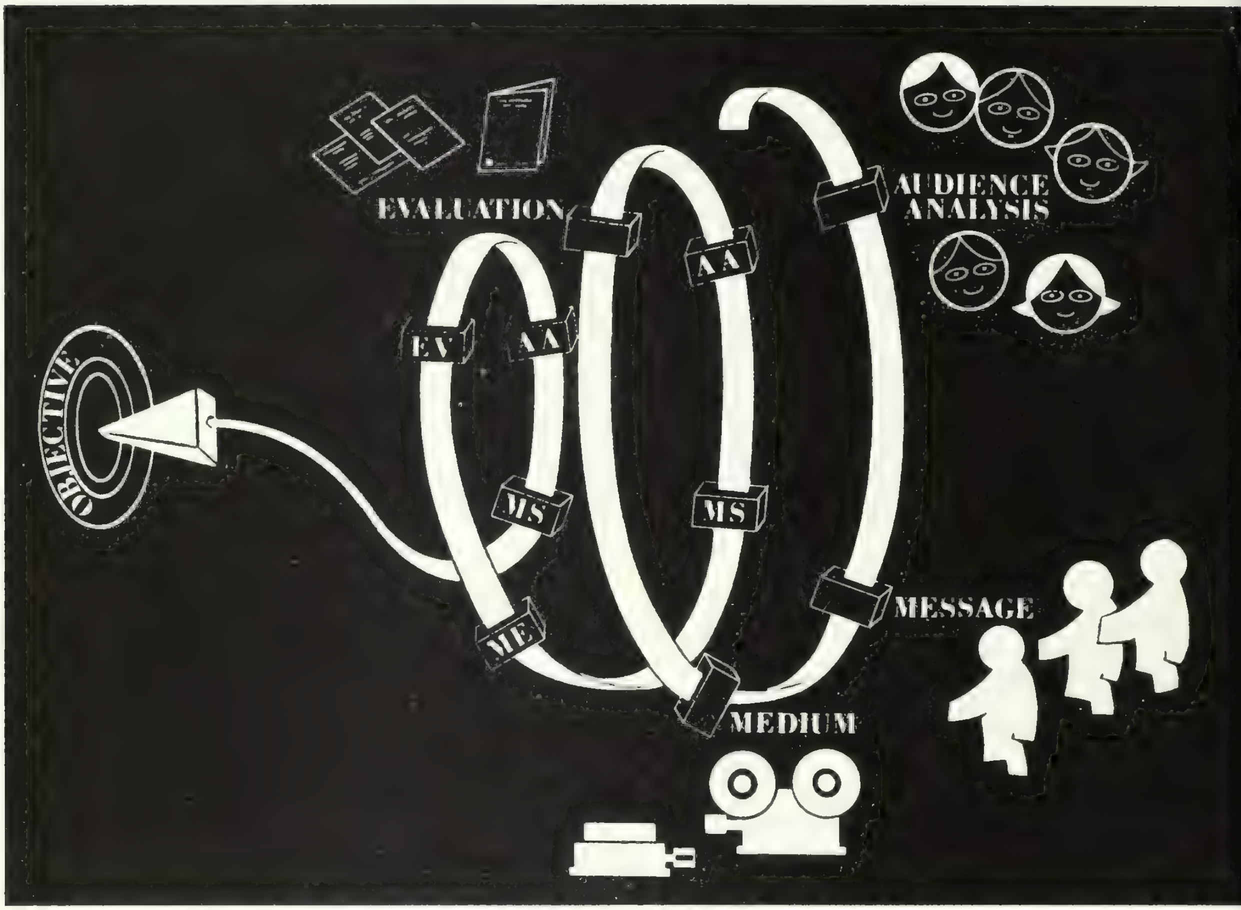

Figure 1.--*Interpretive planning is an ongoing process, providing for continual refining of the interpretation until the original (or revised) objective is met. This "Communication Spiral" shows the sequence of each cycle from audience analysis to evaluation.*

correlation between visitors motives for taking a river trip and which types of interpretive media they preferred. Roggenbuck found that user motives varied and included solitude, achievement, self-awareness, excitement, nature study, affiliation, and status. He then correlated the relative strengths of these motives between various subgroups (day *vs.* overnite users, experienced *vs.* inexperienced, commercial *vs.* educational, seasonal, etc.), and found that in certain settings, a group with one set of motives may have a different interpretive preference than those with another set. Thus in selecting between self-guide and conducted media, the manager must unde stand his visitors' basic motivations. Roggenbuck's findings are supported by the following situation that occurred at one Forest Service visitor center. The center staff offered to conduct canoe trips one season, which attracted little or no public interest. The staff concluded that these trips, though offered in a wildernes type setting, were in conflict with the visitors' stress release/solitude motivation. A switch to brochures and other sel guided media proved successful.

After identifying target audiences, the nager must match the *message* with the audience and define *objectives* for each situion. The message and the objectives are sed on the needs of both the audience and nagement, and are drawn from a comprehenve story inventory of the site.

The objectives can mean the difference tween a "blah" and an exciting experience. ter all, if the manager doesn't know what wants to accomplish through interpretaon, the visitor will most likely be lost a haze. Therefore, objectives should be ecific and measurable, and should be based clear resource management goals. An ample of good direction is seen in the ver-oriented programs at Lord Stirling rk in New Jersey:

- To give visitors an enjoyable learning experience that is unique and beyond anything that can be achieved at any other kind of facility.
- To provide foundation experiences for youth which lead to positive attitudes toward the environment.
- To demonstrate that there are many possible uses of natural resources, some of which will bring positive benefits to man, others which lead to negative consequences.
- To demonstrate how visitors can actively, effectively, and creatively involve themselves in correcting the abuses of their environment.

they have at Lord Stirling, objectives ould go beyond awareness and motivate sitors to action (see Fig. 1 in Wagar 76).

The third step is the selection of at tool, or *medium*, which is best suited delivering each message and meeting obctives (Hanna 1975 , Sharpe 1976). Be are too, of the medium's appropriateness the setting, i.e., a message repeater y work well in some urban river settings, t could only serve to irritate visitors a wild and scenic river. The media ich are finally selected should then be it into an integrated and effective sysm. This system should be outlined in an terpretive Plan for the unit.

The fourth step in the refinement cle is *evaluation* of the interpretive ogram's effectiveness. Guidelines for is critical step are discussed in artiles by Wagar (1976) and Screven (1976).

UTILIZING INTERPRETATION AS A MANAGEMENT TOOL

One aspect of interpretation which managers often overlook in their planning is how it can alleviate certain user problems. Inventory your own user problems. What are they? Where and when do they occur? How extensive are they? Who creates them and why? How can interpretation reduce both the problems and the costs associated with them? Once these questions are answered, the manager is ready to define, in detail, his target audiences and message objectives.

For example, boating accidents were a problem on the Ashley National Forest in Utah. The Forest staff, in cooperation with the Coast Guard Reserve, set up a program in which three times a week boater safety talks and demonstrations are given at various campsites from a boat on a trailer. The Virginia Game Commission has another approach, using puppets to demonstrate elements of boating safety.

How about other water-related accidents? At the Park Service's Ozark Scenic Riverways unit in Missouri, a large, backlit transparency graphically shows water safety precautions. By using cartoon figures and *no* text, various problems and hazards (drowning, flooded campsites, waste disposal, etc.), as well as the proper response or preventive measures are illustrated. It is displayed in a riverside visitor center and its design draws viewers to search for all the situations illustrated. A popular exhibit, it has excellent possibilities for showing rules and regulations in a more positive manner.

Is there a problem with user dispersal? The answer might be found in developing a canoe orienteering program which prepares visitors for safely leaving the major routes and traveling less congested areas; or, install a low-power radio transmitter along major highways and direct river users away from sites already at capacity by telling of other sections in the area which can still meet their needs. These radios can reach up to 80 percent of your visitors. Or you could adopt the Bitterroot National Forest's idea of a brochure which shows, by the thickness of the trail line on the map, the amount of traffic on each route.

If you anticipate strong public reaction when initiating a new regulation or prohibiting a popular activity at a heavily used site, consider what the National Park Service did. The quantity of fish that was wasted and dumped into garbage cans resulted in a loss of wildlife food, and made it necessary for the Park Service to prohibit fishing from the famous "Fishing Bridge" at Yellowstone. Using interpretation as a tool, they installed TV monitors at the bridge and showed video tapes which discussed fisheries resource and the reasons for the prohibition. The anticipated outcry never came. The key was in explaining the "why".

INTERPRETIVE SERVICES

Self-utilized Media

Once the interpretive planner has gone through the planning steps and analyzed user problems, what is the likely outcome? The following pages describe several facilities and media which have been developed for visitors to river-oriented areas across the country by using this process. Contact the unit or agency mentioned for further details on those services which could add sparkle to your own programs.

Publications

Printed media are often the first to be considered by many interpreters who deal with river users. Publications have an advantage where visitors want to learn at their own speeds and in their own groups. They can often deliver more information than many other media forms. The pamphlets or brochures can also be taken home and studied in more detail. Printed materials are particularly good in those settings (wilderness, etc.) where conducted activities are not appropriate.

One major use of the publication is as a river guide for canoeists or boaters. Stress practicality by printing on waterproof paper and producing it in a pocket-sized format (about 4 inches x 8 inches). Pocket-size may necessitate printing it as a booklet showing sequential river sections on each page; on a single long sheet that accordian folds into a smaller publication; as a large road map, or rolled like a scroll. The last three forms may be preferred because they show a long, unbroken stretch of the river and are easier for visitors to use to orient themselves. The scroll is often preferre[d] because of its obvious utility.

The guide to Oregon's Wild and Sceni[c] Rogue River is an example of a complete river guide. Printed and folded as a lar[ge] road map, this guide shows almost the entire wild and scenic section of the Rogue River on a single side of the sheet. Key[ed] to mileage points and landmarks, information which deals with river conditions an[d] is of interest to boaters is printed in blue, while interpretive messages are interspersed in black. In addition to th[e] river guide, the publication includes sections on outdoor manners, boating safety, recreation facilities, an overview of the history, vegetation, and wildlife of the Rogue River and sources for further information.

When publications include informatio[n] on site and food selection, fires, equipment, and waste disposal, they become val[u]able in handling pre-trip requests and ca[n] be distributed at launch points or throug[h] outfitters, chambers of commerce, or sporting goods suppliers.

Publications can also be used to interpret special features along the rout[e:] an old mill, miner's cabin, or Indian sit[e.] If you want to avoid attracting increased river use to a remote area, while explain[ing] the unique features to those who do visit consider following the Bureau of Land Management's (BLM) example. BLM produced a small brochure, "Of Gold'N Men", and ma[de] it available at the register box which wa[s] located at an old cabin near a Rogue Rive[r] campsite. The brochure is not available anywhere else; thus, only river users hav[e] access to it.

In developing all media, including publications, follow the principles of go[od] advertising and design. Make sure the pu[b]lication communicates rather than smothering the reader with words.

Interpretive Trails and Tours

In a sense, the above river guides a[re] self-guided river trails. But, interpretive canoe trails are becoming increasing[ly] popular. The St. Croix self-guiding cano[e] trip (Minnesota State Parks) which follow[s] a popular wild river is a good example of

.s medium. Here, riparian ecology, ıatics, and wildlife ecology have been erpreted for the visitor. To keep the erpretation in mood with the wild set-g, brochures with maps keyed to mileage numbered points may be the best medium. dmark trail guides displaying photos of area's unique features are also good ices. Elsewhere, interest points may marked with signs, buoys, numbered ts, or other structures, but *only* when se do not intrude on the visitor's erience.

Don't dismiss the unusual. At Virgin ands National Park, an *underwater* trail been set up. Visitors can take snorkle sons before attempting the underwater te where they read the labels through ir face masks.

The more common interpretive trail rts the *shoreline*, adding to the itor's knowledge of river ecology from re through the use of labels, message eaters and brochures. At Patuxent er Park in Maryland, a floating board-k traverses a marsh and features a -foot observation tower from which itors can watch waterfowl (fig. 2).

Before developing any trails, check r audience analysis. Does the medium t the need? Are the message and loca-n such that the visitor will use the erpretive resource? A canoe campsite ld be the wrong location for a land-ed trail, if the majority of boaters use river because of its solitude or the llenge it offers. This group may not be eptive to interpretation.

When selecting and designing media land-based trails, keep in mind such ential problems as vandalism, vulner-lity of the tread to boat waves, and r conflicts. Some of these problems e developed at a streamside trail near ttle where joggers and walkers have come o conflict; and, on a braille trail on George Washington National Forest rginia) that was routed near a favorite shing spot and has had its guide rope cut eatedly by antagonistic fishermen. Re-ber, too, while drawing attention to ique features improves the interpretive source, it may also encourage vandalism the feature.

Figure 2.--*Floating boardwalks and waterfowl observation towers, such as these at Patuxent River Park in Maryland, expand your self-guided opportunities.*

Special Services

Wayside exhibits, interpretive signs, and self-activated recorded messages also have a place in the world of interpretation. Use them at launching points to orient users, along the river to interpret special historic or natural features to boaters, and at wayside stops along roads to explain the river to auto travelers.

The low-power radio transmitter offers exciting possibilities. The transmitter is installed at a strategic point along a highway, and visitors can tune into the special announcements by switching their car radios to a specified frequency. These messages can be changed hourly to give visitors current information. Studies show that over 75 percent of the visitors are reached through the use of this method, indicating the radios may be invaluable in delivering safety messages, diverting canoeists to lesser used routes, announcing fire conditions, and making other announcements essential to visitor safety and

enjoyment. New equipment developments give the transmitter a range of up to 5 miles, increasing its usefulness.

Unmanned information stations provide more opportunities. Whenever possible, take advantage of existing historic or other unique structures for visitor contact stations (fig. 3).

However, it may be necessary to build a facility which meets your special needs. One such facility is the stream profile chamber located on a self-guided trail on the Tahoe National Forest (California). The chamber attracts several hundred thousand visitors each year, giving them a first-hand look at the dynamics of a live stream and showing the importance of watershed management in maintaining a healthy stream (fig. 4).

A Word About Visitor Involvement

Although visitor participation is recognized as one of the best ways to promote effective and enjoyable learning, most interpreters feel interactive exercises are associated only with personal services. However, interaction should be a part of *all* media whenever possible. Excellent sources of ideas for self-guided media are the articles by Screven (1974, 1976) which have been published in Museum News and other publications. Dr. Screven's work with exhibits at the Milwaukee Public Museum and the Smithsonian Institution show the value of such tools as small, hand-held teaching machines with punch cards, rub-off response dots (fig. 5), "magic pens" that reveal answers, and other simple interaction devices. Visitors can use these tools to record their answers to questions asked on exhibit or trail labels, tour booklets, or tape-cassette messages. The results of pre- and post-tests and the extent of visitor interest have shown these interpretive tools to be highly effective.

Personal Services

By far the most effective and flexible interpretive medium is the personal contact. It allows for use of all the senses; feedback to visitors' questions; the tailoring of presentations to fit visitors' backgrounds, abilities and interests; flexibility in providing changeable messages; guiding interaction with and among visito effecting attitude or behavior change; an protecting unique features.

Conducted Trips

On Foot.--Guided walks and wades are common activities along rivers. They are easily arranged, involve visitors directl with the river, and rely on rather simple equipment and safety measures. By providing visitors with hand lenses, thermometers, dip nets and seines, collection bottles, water quality test kits, and some guidance, they can have an exciting time doing their own interpretation of river systems. The water investigation, developed for use with Forest Service Environmental Education Workshops, is a very popular activity that leads visitors to their own conclusions rather than feeding them answers. Riveredge Nature Center near Milwaukee supplements similar field investigations with an excellent list of follow-up activities. Students are asked to find out how sewage affects water animals, to help clean up a pond, to encourage parents not to use detergents with phosphates, etc. Teachers report th the program's objective--to encourage groups to develop an action plan to resolve a local environmental problem--has repeatedly been translated into action.

In planning programs, consider ways to insure that visitors are properly prepared for the trip (good footwear, clothing, etc.). Also, keep in mind nece sary safety precautions (i.e., avoiding slippery rocks, extremely cold water, steep dropoffs, dangerous currents). Pro grams should not only result in heightene visitor enjoyment, but also in behavior that reflects respect for stream life, equipment, and regulations.

By Canoe.--The popularity of guided canoe or float trips makes them a highlight of many interpretive programs. Visitors usually rent or bring their own canoes, although some host agencies furnish canoes, paddles, and life vests for the trip.

In urbanized areas, these trips can b a dramatic interpretive tool. At Lord Stirling Park in New Jersey, canoe trips range from 2 to 6 hours and visitors pass from rural to industrial settings. Durin

Figure 3.--*Consider capitalizing on the interpretive values of historic structures. This mill house at Markham Springs, on the Mark Twain NF in Missouri, was converted to a popular mini-visitor center.*

Figure 4.--*Through these windows, visitors to the unique Stream Profile Chamber on the Tahoe NF get a below-surface look at a live mountain stream and the trout and other life it harbors.*

the trip, they experience drastic changes in water quality. Visitors' subsequent involvement in flood plain zoning ordinances and water quality legislation is a good indicator of the trip's impact.

One variation of these trips are the popular inner tube and air mattress float trips offered at some National Park areas (fig. 6). Groups study river ecology, comparing findings between quiet pools, riffles, and marshy edges.

Areas which offer longer conducted river tours have often found these trips to attract individuals who want the security of a guided trip, but aren't necessarily interested in interpretive activities. In these cases, the interpreter serves more as a resource person than as an instructor and facilitator, and must be sensitive to his audience so as to avoid an overkill with too much interpretation. These canoe tours help show visitors safety skills and low impact river use, and at the same time are an excellent opportunity to add to visitor understanding of river management.

Interpreters must give close attention to potential safety problems. On canoe trips at Lord Stirling Park (New Jersey), children under 12 years are permitted only if they travel with the parent in their own personal canoe, and all participants must sign a release of responsibility. Such a release, however,

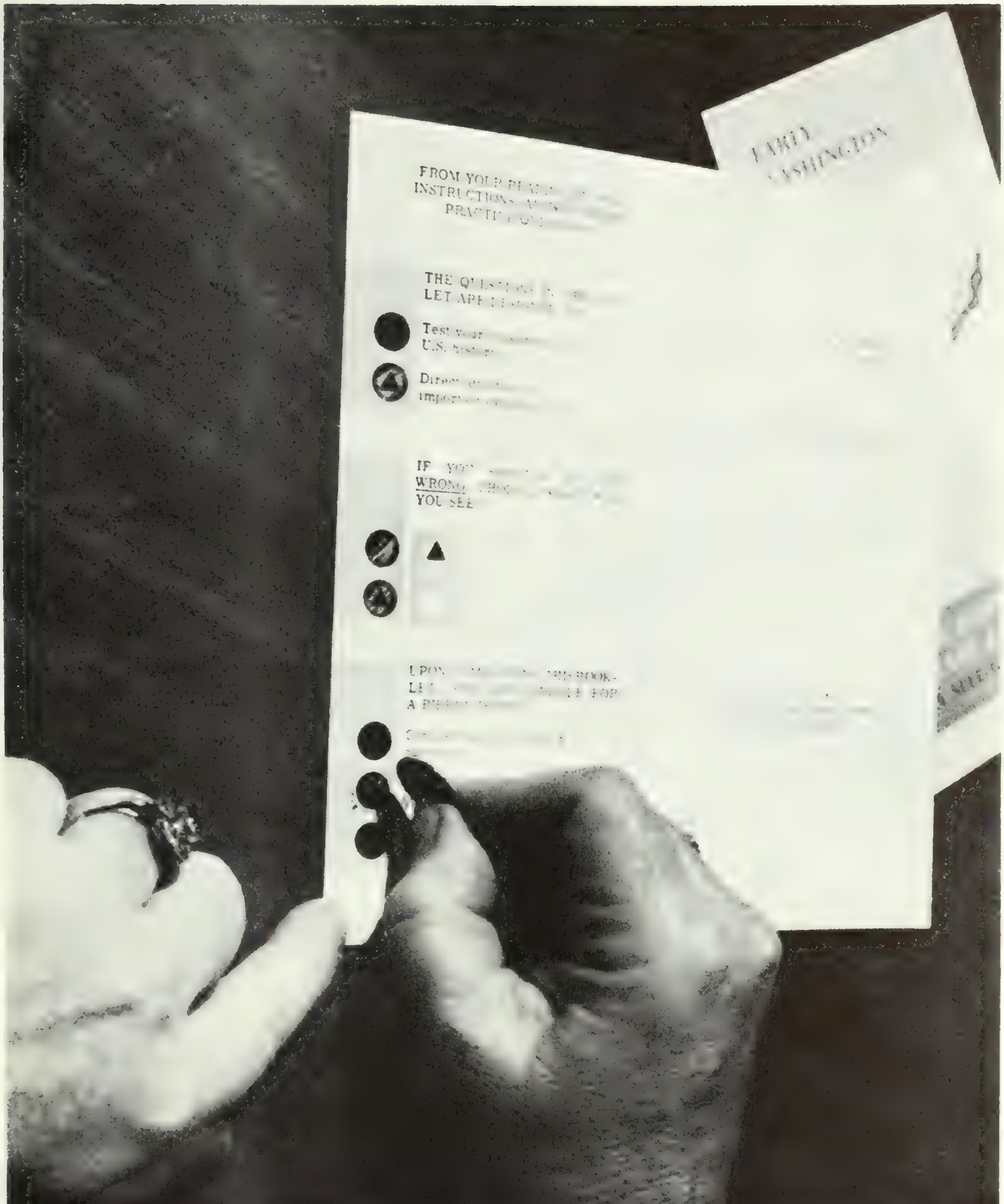

Figure 5.--*Visitor interaction should be a major goal of interpretation. This self-guided tour booklet, used at the Smithsonian Institution in Washington, D.C., encourages learning by providing feedback. Visitors receive booklets or tokens as a reward for perfect scores. Such tools could be applied in all interpretation.*

Figure 6.--*Float trips down the Merced River at Yosemite National Park have grown so popular that, in order to protect both the resource and the quality of the trip, the Park Service has had to offer them by reservation only.*

is no substitute for safety precautions. Programs at other sites have additional rules: no more than two adults to a canoe; all participants must wear a life jacket and know how to swim; everyone must wear tennis shoes as protection from broken glass or sharp rocks; the naturalist travels the route within 7 days before the scheduled trip to become familiar with the route and possible dangers; and, each trip must have an interpreter and an assistant who brings up the rear, and both people must be capable swimmers with water safety training.

Demonstration and Skills Program

Many concepts can be interpreted in a dynamic way by using demonstrations. Workshops on river skills can't help but attract audiences. At Yellowstone National Park, a demonstration on fly fishing, fly tying, casting, and fishing strategy is a popular program with visitors and park managers. Visitors learn skills which help them to better enjoy their sport, while managers get a chance to introduce Yellowstone's fisheries management and catch and release program.

Family canoe workshops covering
noeing skills, safety, river reading,
d ecology (fig. 7) are becoming com-
n and proving worthwhile. One such
rkshop, offered at a Canadian nature
nter by Edmonton Parks and Recreation
partment, includes an actual canoe trip
wn the Saskatchewan River during one of
e five skills sessions.

These workshops are of direct bene-
t to the visitor, placing him in the
le of a river user and bringing him
oser to the water resource. In these
tuations, resource interpretation takes
a new meaning for the user. At the
me time, he learns how to be a better
ver user, how to better enjoy a water
ort, and how he can help to minimize
me river management problems.

esentations

In contrast to guided walks and trips,
oup presentations while on a boat tour
n allow the use of a wider range of
media. Interpreters may present on-deck, audio-visual programs, children's programs, guided walks on-deck and on-shore, as well as developing exhibits, and providing general informational services.

In California, Forest Service naturalists give presentations during boat tours of Lake Tahoe, where they encourage discussion of water management and obvious pollution problems. On the other hand, the Helena National Forest in Montana, stretches its limited budget by cooperating with private riverboat tour operators. Forest staff provide private tour guides with basic information and training assistance, while showing them the need for specific messages regarding fire safety, resource management, and user problems. As a result, passengers hear land management messages from the private sector which adds a degree of acceptability.

Campfire programs at canoe campsites are another possibility. Sites for these

Figure 7.--*The 75 participants who showed up for a canoe skills workshop at Trees for Tomorrow Camp in northern Wisconsin required a staff of about 17 instructors, most of whom were experienced volunteer instructors. Such skills sessions are extremely popular and can be valuable in encouraging low-impact river use.*

programs must be selected with caution when in wilderness-type settings, so as to make sure presentations are patronized, but that they don't infringe on the visitor's back-country experience.

Don't limit the use of audio-visual presentations to interpretation alone, they also offer countless training opportunities. In one successful slide program on canoe skills, each visitor is given two cardboard cards--one green and one red. After showing a short series of informational slides, a question slide is flashed on the screen and visitors are asked to answer the question by holding up the appropriate colored card. For example, a slide showing two alternative routes through rapids, the green route and the red route. The audience's understanding of the subject is noted by the number of correct colored cards held up. The interpreter then encourages group discussion which clarifies the subject or otherwise adjusts the emphasis of the presentation. This process has proven beneficial to the visitors and the interpreter.

Other Personal Contacts

Roving contacts by canoe rangers is another way to reach river users. On the Current River in Missouri, Park Service interpreters travel the river in decked canoes, equipped with seines, minnow traps, and other equipment for use by any visitor who wants to participate in informal river studies.

Environmental work projects can also have great educational value. Whenever a group is out cleaning up trash at a canoe campsite, building stream channelization structures, or working to halt pollution or erosion, they become very receptive to interpretive messages.

Program Balance

When designing the overall program, remember that balance is the key to effective interpretation. Visitors come with all sorts of backgrounds, abilities, and needs. It takes a carefully designed composite of media to effectively communicate your message to all of them.

The comprehensive program at Lord Stirling Park is a good example of balance. Their "Marsh Mullers" (4- to 7-year olds) investigate marshes and streams. There are also the "Swamp Stompers" (8- to 12-year olds), "Indian Lore" groups (which study Indian canoe skills, food gatherin along rivers, etc.), and "Conservation Corps". (This group of 7th to 9th graders deals with management techniques water sampling, stream clearing, erosion control, wildlife management.) There ar also all-day "Wetland Ecology" canoe sessions for grades 10 through 12. Thes are supplemented by a wide range of work shops and tours for adults and family groups.

Patuxtent River Park (Maryland) offers a wide variety of less structured activities. Two boats are available for river studies while 12 canoes can be reserved for recreational use. A wetlands boardwalk, mobile bio-van (equippe to monitor river environments), river orienteering course, fishing trail (requiring a special permit for use), an homemade raft regatta are just some of the program's activities designed to appeal to a wide spectrum of visitors.

GETTING THE JOB DONE-WHERE TO GO FOR HEL

Listed among the references are seve books which will help guide development interpretive programs. General guidelin can be found in the publications by Brow (1971), Tilden (1957), Sharpe (197 and Alderson and Low (1976). These contain information basic to planning, media development, and program administration, as well as basic interpretive philosophy. For specific ideas revolvin around water-related activities, consult books by Van Matre (1972, 1974), Hammerman and Hammerman (1964), and others. For content and for some beautiful examples of the magical side of interpretation, be sure to read Mae Watts' (1957) book (it's a classic), as well as those by Eckert (1967) and Dillard (1974).

Having the knowledge is one thing, but getting the job done is quite anoth A major barrier to program development the retaining of knowledgeable personne Try to hire trained interpreters, eithe full-time or seasonal, who have the nec media and communications skills. Howev budgetary, personnel, or other limitati may force you to turn to other sources

. To accomplish initial planning for rpretation on the Eleven Point River, Mark Twain National Forest contracted a University. The school did the ntories and made recommendations on a and facilities. The Siskiyou onal Forest in Oregon turned to local nteers for the production of a trail log the Rogue River.

Many other National Forests have found nteer interpreters to be an invaluable ce of help, with one visitor center ng trained a cadre of about 40 individ- . There are few if any limits on where e giving people can be utilized-- rams, presentations, demonstrating eer river skills and crafts, producing a, or as speciality experts to help ine story opportunities along the r route. Staff at the Voyageur Visitor er on the Superior National Forest nesota) turned to volunteers for help eaching Boundary Waters Canoe Area A) visitors. The call for assistance answered by members of an Outward d group who were looking for a chance se their skills while serving others. group conducted 2-hour skills sessions BWCA visitors. The audiences were t into small groups which moved from ion to station, learning and practicing various skills taught by two Outward d volunteers located at each station. picked up tips on paddling techniques, and cook fire safety, low-impact ing, portaging, map reading, and many r skills.

Special university programs such as ent internships, senior practicums work-study are other excellent sources rained assistance.

One source of outreach help that is n overlooked by remote resource units interpretive organizations within the s from which most of their visitors come. rpreters can contact these groups, invite on a show-me trip through the resource , point out user problems, and then est possible ways in which the visiting rpreters might incorporate some of the urce management needs of the area into r urban programs. Some at-home ibilities include a trip planning work- for wilderness travelers and a message aign aimed at educating city dwellers t how their consumptive habits and vities directly effect the management of distant resource units. These interpretive organizations may represent county and metro park systems, private nature centers, State and Federal agencies, universities, and museums. These groups can often reach several hundred people with one program and are thus invaluable in reaching potential visitors *before* they leave home.

GUIDELINES

- When planning the overall program, follow the interpretive planning steps in proper sequence as shown on the "Communication Spiral" (fig. 1).

- Base messages on Tilden's (1967) 6 principles of interpretation, outlined in his book.

- Design a unified combination of media which effectively communicates while it complements the river setting.

- Whenever possible, use participatory activities or skills sessions to convey resource concepts.

- Strive to motivate and prepare visitors to do their own interpreting.

- Make quality and effectiveness of interpretation the primary concern:

  (1) Provide for careful personnel selection, training, and periodic evaluation to assure quality of contacts.

  (2) Keep all in-place media maintained in a good quality condition.

- Inventory hazards and provide FULLY for visitor safety in all river activities.

ACKNOWLEDGMENTS

The activities outlined in this paper were shared by a number of individuals and agencies involved in river interpretation. Of the many respondents, special thanks go to:

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USDI Bureau of Land Management, (Terry Kincaid, Cottonwood Resource Area, Idaho; and Kenneth Mak, Rogue River Project, Oregon);

and the following individuals: Dr. Gabri Cherum, Ohio State University, Columbus, Rich Dolesh, Patuxent River Park, Riverda Maryland; Walter Jones, Lord Stirling Par Basking Ridge, New Jersey; Andrew Larsen, Riveredge Nature Center, Newburg, Wiscons staff of Minnesota State Parks; and Dr. J Roggenbuck, University of Wisconsin at St Point.

APPENDIX

Audience Analysis Checklist

Descriptive Data

- Origin
  - Urban or rural?
  - Local or distant?
- Occupation and economic level
- Size and nature of group
- Personality traits (if applicable)
- Age
- Sex
- Education
- Types of questions asked

Attitudinal Data

- Interests
- Expectations and basic motivations
- Beliefs and prejudices
- Values
  - Hard to get a handle on without stereotyping
- Goal-oriented vs. receptive
  - When and where are they in either state?
- Present knowledge of subject
- Interest in subject
  - Hostile or Apathetic?
- Attitude toward Forest Service
- Attitude toward interpreter!

Behavior Data

- Mode of transportation
  - Any access problems?
- Purpose of visit
  - Restrooms?
  - Along for ride?
  - Definite goal?
- Length of stay
- Attendance:
  - Daily, weekly, and seasonal cycles
- Frequency of visits
  - Repeater or first time?
- Traffic flow pattern
  - Sequence of visitation; Route
- What is their destination?
- Points of visitor concentrations
- Where do they stay during visit?
  - Confined to specific area?
- What are the expected activities during their stay?
- What other activites are related to their on-Forest visit?
  - Special event?
  - Attraction?
- Who *does not* participate in VIS services?
  - Why not?
    - Access?
    - Inability?
    - No interest?
  - What impact do they have?
  - Do you want to reach them?

TVA'S ROLE IN RIVER-ORIENTED RECREATION

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ABSTRACT.--The Tennessee Valley Authority, in cooperation with other agencies and organizations, has surveyed a number of streams, acquired public access, developed parking and recreational facilities, written descriptive brochures, rated canoeing difficulty, and regulated streamflows from its dams. Providing use, not restricting it, is the present course. TVA will monitor the river resource to assure protection.

Every river is a valuable natural resource with a variety of potentials and should be dedicated to the uses for which it is best suited. The Tennessee River, which flows through portions of seven Tennessee Valley States, was a mud-and-flood river in the early 1930's. The need for water control was overriding and the creation of cove-studded lakes added far more to recreation use and scenic beauty than it subtracted. TVA has also recognized that other streams are recreational resources which can complement the system of reservoirs, and has actively pursued a program to encourage public use and recreation development of these waterways.

Some of TVA'S early efforts in behalf of river conservation were on the Obed and Buffalo Rivers. Both were recognized for their outstanding scenic features and promoted by TVA before the passage of the National Wild and Scenic Rivers Act of 1968. In 1965 local citizens requested TVA to study the Obed system for possible reservoir sites to alleviate flooding in the Emory River system. During this investigation, TVA made intensive studies of the Obed's natural and scenic qualities and developed a concept designed to take advantage of these qualities. The proposed flood control project was ruled out. Subsequently, in accordance with the National Wild and Scenic Rivers Act of 1968, the Bureau of Outdoor Recreation (BOR), the State of Tennessee, and the TVA undertook a study on the Obed River. This study concluded that the Obed River was eligible for inclusion in the National System and recommended that TVA and the State of Tennessee implement this plan. TVA has expressed willingness to share administration and development of the Obed with the State.

TVA and the State of Tennessee in 1967 concluded that the Buffalo River's highest and best use would be as a State scenic river. A proposal to develop this stream was approved by the TVA board in 1968 but was never implemented due to the passage of the National Wild and Scenic Rivers Act, which designated the Buffalo as a study river. In accordance with that Act, TVA is now assisting BOR and the State of Tennessee in studying the Buffalo to determine its qualifications for inclusion in the National System.

TVA has also cooperated with the State of Tennessee in preparing and implementing a master plan for development of the Hiwassee River as a State scenic river. TVA'S role includes:

1. Providing favorable daily streamflow during the peak recreation season.
2. Providing scenic easements on TVA land along the river.
3. Development of public use recreation areas.
4. Economic development through local citizens to provide needed facilities and services in the area.

As a result of TVA efforts and the favorable streamflows, the first successful river outfitter in the Tennessee Valley was established for the Hiwassee 6 years ago. This venture encouraged a number of similar business ventures on the Hiwassee and other Valley streams. Technical and economic data are made available to entrepreneurs who wish to expand these services to other suitable streams. At the present time there are 13 operators on 7 streams. TVA is also

working with the State of Tennessee on developing the Tennessee portion of the French Broad River as a State scenic river.

MANAGEMENT PROBLEMS

While studying the Buffalo and other streams, the TVA noted several problems that restricted public use. The most obvious was lack of public access. Access was restricted mostly to bridge crossings and was usually over private property. Parking at these locations was almost nonexistent; in some instances cars were towed away because they blocked or impeded the flow of traffic. Launching of canoes was difficult to almost impossible, often down steep banks. Three years ago, only three areas had public access to Tennessee Valley streams with developed facilities for parking and canoe launching. (These were on TVA dam reservations at Douglas, Cherokee, and Norris; one by USDA Forest Service on the Hiwassee River, and two by the Tennessee Wildlife Resources Agency on the Clinch River.)

Another problem was lack of streamflow information. Stream gages were located on most Valley streams, but information correlating streamflow with canoeing conditions was lacking. There was no systematic method of making this data available to the public.

The third major problem was a general lack of canoeing information for streams. Data on stream characteristics, stream suitability for canoeing and floating, and maps showing access points were not available. There was no information on difficulty ratings: would these streams be safe for family outings or should they serve the danger-loving white water enthusiast? Put-in and take-out points were only known by word-of-mouth and located by trial and error.

To solve these problems, TVA started a program to assist in guiding recreation development and use of Valley streams. Stream surveys were begun to provide an inventory of the scenic and recreational streams in the Valley and determine how they could best serve the recreating public. This program will:

1. Identify streams with "significant recreational potential."
2. Evaluate and classify these streams according to their recreation capabilities.
3. Select sites for development to enhance public use and enjoyment.
4. Work with appropriate State and Federal agencies to develop these sites.
5. Publish brochures to help the pub enjoy the recreation attributes c each stream.

A list of 60 streams was compiled cooperatively by TVA and Valley canoeing groups. A field survey determined:

1. Maximum and minimum flow for good boating on streams with available gages.
2. Most desirable scenic stretch.
3. Stream "difficulty rating" so canoeists can choose streams appr priate to their canoeing skills.
4. Potential location of put-in and take-out points for public access
5. A rating for each stream based on esthetics, streamflow, water qual ity, road access, and overall recreation capability. This rati allows comparisons with other streams.

We determined a need for over 200 pub access areas on 40 Valley streams. Those streams with suitable streamflow during th recreation season, located near major population centers or major visitor attractio and capable of supporting a significant amount of recreation use, were given devel opment priority.

Access points on the selected streams are being acquired throughout the Valley. Launching areas with adequate parking and sanitary facilities will be provided at ea site. Over the past 3 years, 18 sites hav been provided, 15 of which were acquired a constructed by TVA.

We anticipate working closely with ot Federal, State, and local agencies in deve opment of these access points. The State Game and Fish, Recreation, Conservation, a Highway Departments in the Valley have all expressed strong support and willingness t cooperate and carry out this program.

A series of brochures on the Elk and Obed Rivers, and principal recreation stre in the Little Tennessee River watershed ha been prepared and published. These brochures provide information on access point and streamflows that are acceptable for

oeing. Other brochures on Valley streams being prepared.

To assist the canoeist in planning his ings, a 24-hour telephone recording gives latest streamflow on selected streams. o, daily streamflow readings and weekend erhouse discharge forecasts are published the major daily Valley newspaper. Con-lled release of water at TVA dams has tributed much to recreational use of tain streams. Scheduled releases over past 8 years on the Hiwassee and South k of the Holston in Tennessee, and the tahala and Tuckaseegee Rivers in North olina, have made it possible for annual oeing events of local and national sig-icance to be held at times when flows on se streams would normally be too low for isfactory boating.

TVA has also made a effort to facilitate lic use and enjoyment of streams down-eam from its most recent dam construction jects. On the Elk River, scenic easements needed access were purchased on 30 miles the stream while flood control rights e being acquired providing the longest ment of protected scenic stream in the nessee Valley. A similar program is underway to provide access on 28 miles of the Duck River below Normandy Dam, and access and scenic protection on 25 miles of Bear Creek just below TVA'S Upper Bear Creek Dam. These projects will provide regulated flows. Access areas will have boat ramps, parking areas, sanitary facilities, and garbage cans.

In conclusion, TVA is striving to assist interested agencies and organizations in developing the recreation potential of Tennessee Valley streams. Because the use of Valley streams is not as great as the use of streams in other regions, our principal concern is providing opportunities for stream recreation rather than restricting them. At this time we feel that overuse will not be a problem on most of the Tennessee Valley streams, with their convenient access, road systems, and nearby recreation facilities. Increased use can be adequately handled by increasing the intensity of management. However, the river resource must be constantly monitored and evaluated to determine if significant damage is occurring. If it does, you may be assured that TVA will take the lead in protecting these valuable resources.

RECREATION MANAGEMENT PLANNING FOR A MULTI-USE SCENIC RIVER CORRIDOR

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ABSTRACT.--Thirteen Mile Woods is a highly scenic strip of forest land along the northern reaches of the Androscoggin River in New Hampshire. A survey of its visitors--canoeists, kayakers, picnickers, campers, fishermen, and snowmobilers--indicated their desire to maintain the area in its undeveloped condition. Land capability and administrative viewpoints indicate the same minimum development. Design capacity is discussed as a management concept for this land and river corridor.

The Androscoggin River is one of the many scenic resources of rural northern New Hampsire. Its headwaters are in the heavily forested region of Lake Umbagog from where it meanders 161 miles to the coast of Maine, encompassing a drainage basin of 3,450 square miles (fig. 1).

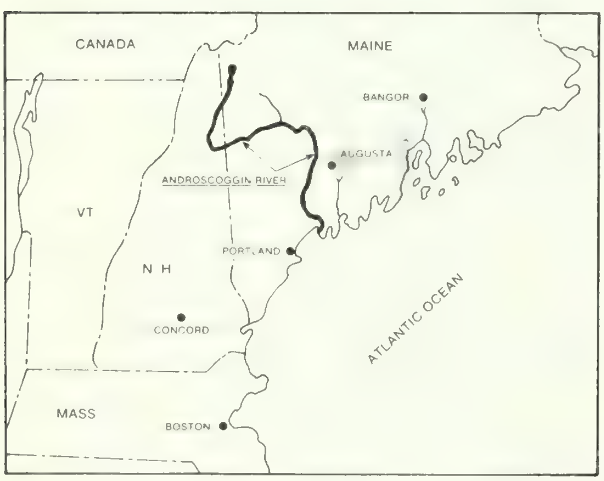

Figure 1.--*The Androscoggin River Basin of New Hampshire and Maine.*

An important section of this historic river basin is the Thirteen Mile Woods Scenic Easement. This is a narrow, 329-acre strip along the west bank of the upper reaches of the river. It is an area that is largely undeveloped and remote in character, lying in the midst of the northern hardwood and spruce-fir forest. Although the Thirteen Mile Woods Scenic Easement does not include the Androscoggin River, the river is the main attractive force and cannot be separated from the actual land area of the Easement.

The "Woods" is presently managed by two private companies, Brown Paper Company (Berlin, New Hampshire), who purchased a 25 percent undivided interest in 1947, and Seven Islands Land Company (Bangor, Maine), a land management company representing the private owners of the other 75 percent. Both companies have observed the change from a primarily log transporting river to one of unique recreational use.

Until 1964, the year of the last log drive on the Androscoggin River, the river was unsuitable for any other use. Since that time recreation has been emphasized. The high quality water provides excellent fishing, the rapids are good for canoeing and kayaking, and the shores provide sites for picnicking, camping, and sightseeing.

The two companies managing this area ave responded to the public's demand for ecreation by realizing the potential of his area and implementing a recreational anagement program. In 1972 both companies ntered into a scenic easement with the tate of New Hampshire, Department of ublic Works and Highways. The main purose of this easement is to ensure the cenic beauty of New Hampshire's Rt. 16 hrough the Thirteen Mile Woods area. his easement gives the State of New Hamphire the authority to regulate development f the area for its scenic beauty and still llows the two companies to harvest timber rom the land selectively.

MANAGEMENT PLANNING

By 1975 the recreational use of the oods and grown to such an extent that the imber companies and State of New Hampshire egan seriously considering the need for a ore comprehensive management plan. They uspected, based on some local experience, hat the fairly recent arrival of growing umbers of kayak and canoe enthusiasts ere conflicting with the fishermen. Morever, they felt the number of visitors may ave exceeded the capacity of the area. hus in the fall of 1975 Sno-engineering as contracted to develop a recreation anagement plan for the woods. This was o include *objectives, policies,* and *lternative* action plans.

Initial review of secondary informaion indicated Thirteen Mile Woods to be an nteresting situation. Although the area s remote in overall character, *a good ighway runs its entire length providing xcellent access to the land and river.* his means there is no simple way of conrolling the use of the Woods. Fishing, amping, picnicking, and sightseeing have een the main historic uses of the Woods; owever canoeing and kayaking are now dentified as "fast comers". The surge in hese last two activities is due to rivately organized races, *commercial out-itters,* and naturally good white water; ams along the river result in an nusually long white water season.

The management planning for the Woods as done using a flow-chart method. The ollowing six major areas of concern were dentified for the purposes of the study:

(1) *Social.*--This includes items such as the easement administrator's desires and objectives, the desires of local residents and government, and visitors' thoughts on the use and management of the area.

(2) *Legal.*--This includes the scenic easement agreement, river control and ownership, land ownership, and the various Federal and State laws.

(3) *Site analysis.*--This category includes soil, water, timber, wildlife, and geology as a basis for determining resource capabilities.

(4) *Recreational use.*--This includes information on the number, type, and timing of users, as well as the identification of use conflicts.

(5) *Outside influences.*--This includes factors such as other recreational areas, improved accessibility, and community support services that are important outside influences in management planning.

(6) *Economics.*--This would include a cost-benefit review of any facilities development, and recognition of the basic costs required to maintain the area.

Most of the necessary information for these categories was available from secondary sources. However, there were some major gaps in information that had to be collected first-hand. For example, it was discovered that little data existed on the number of visitors, by activity, for the area. Also, there were no factual data on such important questions as the level of development desired by visitors, and visitors' perceptions of use conflicts and the existing intensity of use.

The number of visitors using the Woods was determined by actual counts on sample days. On these days two persons travelled the road from 8:00 a.m. until 6:00 p.m. and recorded the number of visitors by activity (an effective but tiring technique). This was done in such a fashion as to reveal: (1) the total number of visitors/activity/2-hour interval, and (2) the total number of *different* visitors/activities/day.

To complement the use figures, personal interviews with visitors were held

along with the counting. The objectives of each interview were: (1) to characterize the person by activity, (2) to determine the level of development they desired for the area, and (3) to determine their perceptions of use conflicts and the current intensity of use.

Because the woods is an area with a strong French-Canadian influence, and many fishermen spoke only French, a questionnaire had to be developed in that language. This aspect of the study proved once again that river planning situations are often unique, and that you must take into account the cultural setting of a study.

PRELIMINARY RESULTS

At the time of preparation of this paper final results of the study had not yet been determined, but following are some preliminary results. Only those results of possible interest in other planning areas are discussed because every river seems to represent a unique planning situation.

Social.--Both local residents and visitors had a strong identification with the "Woods" and would like it to remain as is. Less than 10 percent of the visitors perceived any conflict of activities. The conflicts that were perceived were related to noise and behavior in the campground.

Legal.--The Thirteen Mile Woods Scenic Easement is the guiding legal document for the area. Minimizing any development, and permitting logging, are the main points of this agreement.

Site.--Soil drainage characteristics limit any development to a few select sites. These are the sites already in use.

Economic.--The undercapacity use of the campground and picnic area indicates future facility development should be limited.

Outside influences.--Possible wild and scenic river designation might influence timber management plans. Possible State park development nearby could attract more visitors.

Recreation.--The Thirteen Mile Woods is uncommon in the diversity of its recreational potential as evidenced by the variety of users. This can be observed in the activity breakdown for the average 77 peop[le] per weekday and 141 people on Saturdays an[d] Sundays (table 1).

Table 1.--*Visitors engaged in various activities on weekdays and weekend days*

(In percent)

Activity	Weekday[1]	Weekend day[2]
Camping[3]	3	4
Fishing	43	27
Canoeing	19	31
Kayaking	2	15
Picnicking	16	8
Sightseeing	17	15
Total	100	100

[1] 30 percent are engaged in more than one activity

[2] 38 percent engaged in more than one activity

[3] Camping only

NUMBER OF VISITORS

Because everyone likes to "have a fee[l] for the situation", one kind of useful dat[a] developed in this study was the average number of visitors to the area. During th[e] week the average number of visitors per da[y] was 77, which can be further broken down into activities (table 1). The average number of visitors per day on a weekend wa[s] 141, which can also be divided into activities (table 1). These numbers of people b[y] no means made the area crowded, as they we[re] usually well dispersed along the 13 miles of river. These average figures also do not indicate the fact that on many good weekends few recreationists use the area, although on others (particularly kayak rac[e] weekends) the area is congested, especiall[y] at the best rapids.

The reasons for such light use in a desirable area are not entirely clear. On[e] possibility, though, is location. Thirtee[n] Mile Woods is an hour north of the very heavily used White Mountain National Fores[t] and this may put it out of reach for the average visitor to northern New Hampshire. This notion is supported by the fact that many visitors to the woods are local north-county people. It is only on canoe and kayak weekends, or when the snowmobile

ason has ended in the southern regions, at large numbers of nonlocals visit the ea. A compounding factor is that, cording to our collection of data, this s been an "off" year for use of the area.

CONFLICTS OF USE AND LEVEL OF USE

In the context of these use figures, pecially considering the mixture of tivities taking place, there were very w people who perceived any conflict of e. In fact, less than 10 percent of the isitors noted any kind of conflict when uestioned on this matter. Most conflicts entioned related to noise and people's ehavior in the campground. It was intersting that the fishermen and canoe/kaykers seemed to have little problem coxisting. On weekends of kayak and canoe aces the fishermen apparently used other reas outside the Woods, and left the water o the boaters.

This minimum of conflict turned out to e an interesting point in the study. A umber of persons providing background data rior to the beginning of the study indiated there was a serious conflict between he fishermen, longtime visitors to the rea, and the kayakers. Supposedly kayak ctivities, including their slalom wires, ot in the way of the fishermen. Moreover, t was implied that the kayaker's spent ittle money locally. On the contrary, our bservations indicated little conflict on he river and that the kayakers do use the ocal motels and restaurants.

One reason for lack of conflict may ave been the level of use. When questiond on how they felt about the number of eople present--"too many, just right, or ould accommodate a few more" --most people esponded "just right". The fact that this esponse occurred over a variety of levels f use indicates a great amount of lasticity in defining the number of people n area can sustain on a social basis.

A related, yet probably more important, eason for lack of conflict was people's ehavior. Those few conflicts that did ccur were mostly related to people's ehavior--noise in the campground or aucousness on the part of a very few eople on race weekends. Most people visitng Thirteen Mile Woods seemed polite and esponsible, which is undoubtedly basic to he fact that the Woods receives yearround recreational use in a generally unsupervised manner and yet environmental deterioration is not great.

LEVEL OF DEVELOPMENT

In addition to considerable homogeneity of response regarding the two situations described above, most people were in agreement that maintaining, but not expanding, the existing facilities was the best idea. Currently the camping and picnic areas have a minimum of rustic facilities. A frequent comment at the completion of an interview was "just keep the area like it is".

MANAGEMENT CONCEPT

As previously stated, the final report on this river planning effort was not prepared at the time of this writing. However, some notion of its possible outcome can be presented through the planning concept that will be used. This plan, and the synthesis of information into a plan, will be based on the concept of "design capacity" (Leonard 1976). This states that the management of a resource-oriented recreation area is conditioned by three characteristics: (1) *the desire and expectations of the visitors*, (2) *the capability of the resource to sustain recreational uses*, and (3) *the intensity of management that is available.*

The desires and expectations of the visitor can generally be veiwed as a spectrum of alternatives. At one end of the scale would be those recreation areas where one anticipates encountering many people and where the site might be highly developed in terms of facilities. At the other end of the scale would be those areas where one expects to meet few, if any, people, and where visitor facilities would be essentially nonexistent. In the case of Thirteen Mile Woods, most visitors indicated a desire to maintain the limited, rustic facilities with a use level similar to what exists today.

The capability of the resource refers to the amount and kind of use it will sustain. This feature of design capacity is difficult to quantify in terms of allowable recreation pressure. However, a visual assessment of current site conditions

combined with a resource evaluation for facility development (i.e., sewage effluent, soil foundation, etc.) gives some indication of resource capability. In Thirteen Mile Woods there was little visual evidence of resource damage, and a thorough site analysis revealed only limited areas suitable for development.

Intensity of management concerns the amount of funds and effort an organization is willing to put in an area. This varies, at least to some extent, according to the amount of use and site conditions. For example, the fragile condition of high elevation recreation sites often requires more intensive management to maintain them. By the same token, if administrators anticipate they can only provide a minimum of management, then they may have to consider minimizing use or accepting site deterioration. In Thirteen Mile Woods the administrators desire a low intensity of management.

These three management planning considerations, taken as a group, indicate that Thirteen Mile Woods should remain a largely undeveloped area catering to a small clientele. This would satisfy the visitors, the resource, and the administrators.

Based on our experience in this study, certain aspects of river planning have become evident. One is that conflicts of use as reported by local people appear not to be an accurate indicator of what is actually happening. The easy access of Thirteen Mile Woods and the River creates an unusually difficult situation in terms of controlling use. Although the existing scenic easement provides some guidelines for management, it alone will not ensure the implementation of a responsible management plan.

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PROBLEMS AND CONFLICTS ASSOCIATED WITH RIVER RECREATION PROGRAMMING AND MANAGEMENT IN THE EAST

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ABSTRACT.--Increased river recreation has resulted in conflicts over project development, between landowners and users and problems related to management and administration. Controversies are typically the result of varying attitudes and values, philosophies, and failure of managing agencies to incorporate such considerations in river programs. Most problems and conflicts are symptoms of an uninformed public.

The objective of this evaluation is to lentify in general terms problems and con- .icts associated with river recreation :ogramming and management in the eastern iited States. Three subject areas are con- .dered that in the opinion of the authors onstitute the most significant sources of .fficulty related to stream based recrea- .onal use. These areas include (1) con- :oversies associated with river recreation :oject development, (2) conflicts between ie river user and the riparian landowner, id (3) problems related to management and lministration of river recreation.

To better identify trends, question- aires on the problem areas were mailed to astern State agencies apparently active in iver recreation planning and management. eventeen States, or 68 percent of the 25 tates contacted, responded. In addition ie authors' opinions, knowledge, and direct xperiences regarding the subject in Tennessee, s well as other States, constitute this eval- ation.

CONTROVERSIES ASSOCIATED WITH RIVER RECREATION DEVELOPMENT

A fundamental conflict exists between ie philosophies of water resource development (impoundment, diversion, channelization) and of nondevelopment or preservation (i.e., free-flowing streams). Since most river recreationists in the East use natural or unmodified streams, it seems important to maintain streams in their natural and unmodified state. The increased competition for land and water, however, will continue to influence decisions on the equitable distribution of resource use. As noted by some eastern States, conflicts with real estate development, hydro-electric projects, and certain agricultural operations will persist. There is also disagreement among environmental interest groups as to the "appropriate" utilization of resources.

After certain river resources are committed to recreation projects, it is difficult to ensure that such use will be perpetuated. The increasing popularity of river recreation in the East requires that methods of land and water management be devised. Such management methods will ultimately involve controls and regulations imposed by some level of government. Six or 35 percent of the States sampled maintain river programs that exercise or have potential jurisdiction over designated waterways and adjacent riparian lands. (Jurisdiction is typically the authority to defer certain water resource development projects and acquire interests in land from private owners (Tennessee Department of Conservation 1976)).

The "scenic" or "conservation" easement has been frequently used to control unwanted development on desirable land along many designated project streams in the East. Public receptivity to the concept is typically negative among those immediately influenced by the restrictions. Most property owners identify the easement as an unwarranted and unjustified encumbrance on their land. Subsequently, issues develop that often must be resolved politically. While lawmakers may support the intent of a river recreation-preservation program, many continue to maintain the values and considerations of their local constituencies and are not inclined to evaluate the advantages of river projects to the region or State.

Negative reactions of local landowners whether apparent or implied often result in the deferral or cancellation of river recreation projects. Opposition continues to be a matter of values and attitudes. Landowners confronted by proposed river projects typically raise the following issues.

Individual Sovereignty.--Many individuals purport that implementing certain aspects of river projects contradict the personal options and liberties guaranteed in the Constitution of the United States. It is frequently maintained that no government agency has the right or authority to impose land use restrictions or regulations, e.g., scenic easements, on the private sector. This attitude is most prevalent among farmers along river projects. (In the East most land along the most popular recreation streams is agricultural or forest land.)

Insensitivity of Governmental Agencies.--It is a common opinion that implementing agencies are insensitive to local considerations and entirely preoccupied with the "project for the project's sake". It is maintained that administrators are not concerned with individual problems but only with technical aspects of implementing the program.

Inconsistency of Governmental Policies and Procedures.--A typical criticism of government agencies is their failure to maintain consistent administrative policies. Procedures and methodologies initially presented to the public may change significantly with little or no prior notice.

Incapability of a Bureaucracy to Maintain Effective Liaison with the Local Area.--It is often alleged that government agencies by virtue of their typically complex adm[illegible] trative and organizational structure are incapable of maintaining close contact wi[illegible] local landowners and interests. Further, most administering agencies are far remo[illegible] from project areas and are, therefore, i[illegible] no position to evaluate essential daily considerations.

Encroachment of Government.--Local i[illegible] terests suggest that there are no assura[illegible] that initially established regulations wi[illegible] not be amended in the future to include additional and more binding restrictions. It is often stated that the private secto[illegible] is already unduly subject to governmental regulation without further encumbrances.

Invasion of Community and Personal Privacy.--A common assertion is that proj[illegible] development will promote changes in commu[illegible] and personal life styles by virtue of increased "outside" visitation and use. A fear is expressed that river projects emp[illegible]size and encourage public use and consequ[illegible] impose social problems on the immediate c[illegible]munity.

Landowners Unjustly Compensated For Loss.--Landowners frequently state that t[illegible] government does not provide just compensation for rights of interests acquired. Appraisals do not reflect what many consi[illegible] to be a reasonable market value. Further the subject appraisal cannot evaluate or place a value on intrinsic and implicit qualities inherent in the land, e.g., fam[illegible]ties, history, esthetics, etc.

Technical Aspects of Project Impleme[illegible]tion.--Most individuals influenced or aff[illegible] by the project are unaware of the often c[illegible]plex and technical aspects of implementati[illegible] The various components and intricacies of law, politics, socio-economics, public adm[illegible]istration, and natural resource management are most difficult, if not impossible, to relate or explain to the layman. Efforts [illegible] explain such concepts are necessarily supe[illegible]ficial and typically result in confusion or misunderstanding. The subsequent publi[illegible] reaction is to reject or disapprove of con[illegible]cepts that remain unclear or obscure.

In summary there are two basic issues associated with river recreation project development. First, a fundamental problem of land use commitment must be resolved. It may not be appropriate or desirable to promote river recreation along a stream

apparently committed to significant modification or incompatible use e.g., impoundment, industrialization, etc. Second, the involvement of governmental agencies in resource planning and utilization typically generates local controversy. It is most difficult for an administering agency to establish credibility with landowners affected by river projects.

CONFLICTS BETWEEN THE RIVER USER AND THE RIPARIAN LANDOWNER

There are significant conflicts between the river user and the property owner whose land is adjacent or close to popular recreation streams in the East. The frequency and severity of such problems depend on river location, relative popularity of the site, property ownership distribution (size and number), availability of support facilities, and inevitably the personality of the landowner, the river user, or both.

The most serious landowner-user conflict in the East is trespass. Approximately 65 percent of the sampled States specifically noted trespass as a significant problem on popular recreation rivers (Tennessee Department of Conservation 1976). The primary adverse impact of trespass is the fundamental loss of privacy suffered by the property owner. As previously noted, invasion of community and personal privacy is a fear frequently expressed by residents within areas of increasing popularity. While trespass is often accompanied by problems such as vandalism, litter, fire, etc., the personal impact of encroachment is significant in and of itself.

Trespass on lands adjacent to popular streams occurs for a number of reasons. Such encroachment, intentional or not, usually involves hunting, picnicking, nature study (exploration), adjustment of gear, etc. Campers frequently trespass; overnight canoeing or extended float trips are common on certain rivers as noted by 59 percent of eastern study States (Tennessee Department of Conservation 1976).

Typically, many individuals guilty of trespass are unaware of the infraction. Users often assume that their temporary occupancy along river banks is of no legal or moral consequence. Such ignorance is to some extent a function of insufficient education and inadequate public relations on the part of responsible administrative agencies.

Lack of public access also contributes to the incidence of trespass. Popular float streams in the East will continue to be used whether or not support facilities exist for such activities. Clearly, trespass and its attendant problems will continue to increase on those rivers without adequate management and programming for recreational use.

Litter also causes conflict between the user and the riparian landowner. Littering can be especially intense on rivers where activities like camping and picnicking may cause much abuse to private lands. Litter is often evidence of trespass and indiscriminate use. It should be noted, however, that visitors or users are often accused of littering areas that are in fact popular disposal sites for the local community and have been utilized as such for many years. Like trespass, the litter associated with intense recreational use can be minimized by effective educational and administrative efforts.

Other conflicts arise from property damage, vandalism, noise, fire, poaching, indiscriminate use of firearms, and general disrespect for the landowner. Though not as common as trespass and litter, a single incident can have lasting repercussions. The destruction of one gate or blatant discourtesy to one local resident can promote endless controversy between subsequent users and the landowner.

PROBLEMS RELATED TO MANAGEMENT AND ADMINISTRATION OF RIVER RECREATION

The most serious problem facing river recreation management in the East is overuse (as noted by 47 percent of the sampled States) (Tennessee Department of Conservation 1976). Overuse implies unpleasant user experiences as well as degradation of the natural resource. An increase in the frequency and intensity of trespass and litter are indicative of overuse.

The recreational experience is often adversely affected as more individuals engage in more activities on the same resource base. Competition among recreational activities is apparently intense on certain popular streams in the eastern United States. Of particular note are conflicts between boating (canoeing

and kayaking) and fishing enthusiasts. The degree of conflict is usually a function of space, time, and individual philosophy. Other conflicts include fishing vs. swimming and boating vs. swimming. Although limiting recreational activities, zoning, or both may reduce problems of competition, it is interesting to note that few eastern States have incorporated such management regulations. Only Maine specifically reports visitor use regulation (Allagash River). The majority of the States (53 percent) agree, however, that use should be controlled or qualified in some manner to maintain quality experience and minimize resource degradation (Tennessee Department of Conservation 1976).

While it is generally agreed that river recreation in the East is increasing and that overuse is a critical problem, few States monitor or evaluate stream activities. The only measurements of any consequence are those related to regulatory programs such as creel census, game law enforcement, and boating safety requirements. Since 59 percent of the States surveyed noted that most river users have little or no canoeing or boating experience, there is need to monitor at least the boaters' capabilities and expertise. Five States indicated, for example, that most accidents on popular streams involve novice canoeists (Tennessee Department of Conservation 1976).

The failure of eastern States to satisfactorily monitor recreation activities and thereby address the critical issue of overuse is not surprising when current levels of river recreation programming and planning are assessed. About 70 percent of the States sampled indicated that river recreation planning is a "low priority" with their respective agencies. Approximately 60 percent of the survey agencies have no data or information regarding the relative importance or significance of stream recreation with respect to other outdoor activites. Similarly few States have any basic information about the river user, e.g., age, economic and ed tional background, etc. (Tennessee Departm of Conservation 1976).

In general it seems that inadequate planning and programming contribute as muc to the difficulties of management and admi istration of river recreation as do the attendant problems of overuse. In fact th adverse impacts of overuse are in part a result of insufficient programming, planni and research.

CONCLUSION

The problems facing river recreation programmers and managers in the East are complex. The issues are difficult to asses and resolve due to different values placed on the resource. The recent emphasis on river recreation is in part a product of renewed and enthusiastic interest in envir ment that started in the middle and late 1960's. The often emotion-filled controversies regarding stream preservation and protection still generate confusion and misunderstanding, particularly among local landowners who must necessarily "live" wit the decisions of large and insensitive gove ment bureaucracies.

While politicians and bureaucrats struggle with procedures and methodologies, recreational use on popular streams in the East has increased to the point of intense user competition and resource degradation. Managing agencies have apparently underestimated the impact of stream recreation and failed to provide for appropriate use, facilities, and administration.

The most critical oversight, however, is insufficient information and education activities and an inadequate public relatio program. Overuse, trespass, and landowner-user conflicts are only *symptoms* of the basic issue--an uninformed public.

HOW TO RATION RIVER FLOATING USE: THE MIDDLE FORK OF THE SALMON EXPERIENCE

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ABSTRACT.--Rationing was started when crowding and congestion began to destroy wilderness values. Permits are issued to 32 outfitters; noncommerical parties get the rest. Each outfitter is allowed to launch one party, not over 30 people, every 8 days. Outfitter launch dates are fixed to facilitate their advertising. Noncommercial parties apply for reservations in advance, listing a first, second, and third choice of dates. Launch dates are chosen by lottery. Maximum party size for noncommercial parties is 15 people. Maximum trip length is 10 days. Problems include finding an equitable means of allocating permits between commercial and noncommercial parties, and dealing with people who show up without reservations.

THE PROBLEM

Use on the Middle Fork of the Salmon iver has increased from approximately 1,260 eople in 1966 to over 5,500 in 1976. As his use grew, it became evident that some ype of control was necessary if the Wild iver values were to be maintained. A float rip on the Middle Fork of the Salmon is a ice five- or six-day trip. Before con- rols were imposed, most parties started heir Middle Fork trip on a Sunday or Mon- ay; very few started on Wednesday, Thursday r Friday. Since all parties float at about he same speed, there would be a large group f people travelling down the river together hile elsewhere the river was completely eserted. Wilderness values were lost and roblems of campground shortages and dete- ioration occurred.

It became a common practice for one oat of a party to start out early in the orning and go straight through to the lanned campsite for that night. It was hen the duty of this boatman to defend hat camp against all comers. There were ometimes 150 to 200 people camped on a elatively small area. At each bottleneck, uch as launch facilities, take out facil- ties, major rapids, popular campsites, and oints of interest, there was congestion. ome control on use was needed.

DETERMING CAPACITIES AND CONTROLLING USE

The first step in setting up control was to determine the capacity of the river. Since capacity is a very complex subject on its own, I will only briefly state some of the variables to consider. The river manager must decide whether capacity should be based on daily, seasonal, or a year-long numbers of people. Or should capacity be in terms of use-days on the river, number of boats, or number of parties? Is the limiting factor ecological, physical, or social? These criteria will be different for each river.

Once the capacity is decided upon some type of rationing system must be initiated if the capacity is being exceeded. There are many alternatives. One is making the access more difficult. This might be done by closing roads or trails, removing boat ramps, or by other means. At best, limiting access is a stopgap measure and will only buy time. Eventually, use pressures will overcome even the most difficult access problems.

Another alternative would be to make the trip more expensive. This might be accomplished by increasing the permit price or requiring that each user obtain the services of an outfitter. The opposite

alternative--that of eliminating use by outfitters, would also decrease use, at least temporarily. Still another alternative would be to require a certain level of skill or knowledge before a permit is issued, as is required for hunting licenses in Europe. A national "river-running license" might be initiated.

Use could be cut by limiting the number of trips for which a person is eligible--one trip per year, one trip per lifetime, so many rivers or miles per year or lifetime, etc. At present the most common method is to require a permit and limit the number of permits issued.[1] This is the only system that gives positive control of the number of users.

Any rationing system tends to discriminate against some portion of the public. This discrimination is to be expected and is not necessarily bad. Anytime a Wilderness is established it limits the use on that area for some portion of the public.

THE PERMIT SYSTEM

If a permit system is decided on, how should their numbers be limited becomes the next question. One method frequently suggested is to require that each user apply for and obtain a permit. The individual may then decide whether he wishes to go on his own or hire an outfitter. This sounds like the most equitable method, much like the big game trophy permit system used by many state fish and game agencies, but the mechanics of implementing this type of system make it impractical. A difference between hunting and river running is that the hunter may go any day of the season he wishes, while a river floater is not that flexible. Scheduling launch dates, differences in length of trips, putting together a complete party or family group, and other problems of such a system make it impossible to implement.

[1] *Interagency Whitewater Management Guidelines, Appendix H, lists the major western floating rivers, their permit requirements, and a short description of various permit systems. This unpublished guide is available from Sam Warren, Middle Fork District Ranger, Challis National Forest, Challis, Idaho 83226.*

On the Middle Fork of the Salmon River a fixed number of permits are issued to commercial outfitters; private groups get the rest by lottery. A Forest Service Special Use Permit, modified to fit float-boating outfitters, is issued annually to each of the 32 outfitters permitted on the Middle Fork. No additional permits will be issued but beginning this year they are transferrable. Commercial outfitters are set up on an 8-day launch schedule; each outfitter is allowed to launch one party every 8 days. Maximum party size for outfitters is 30 people, including boatmen. These launch dates normally do not change from year to year; an outfitter that launches on July 2, July 10, July 18, etc., launches on those dates each year. This stability is necessary for their advertising and brochure printing. Beginning in 1976, outfitters will be limited to their past use and many of the smaller outfitters will not be allowed to grow.

The remaining capacity on the Middle Fork is allocated to private, or noncommercial, parties. When an inquiry for a noncommercial permit is received, a general information letter and trip application are sent. The information letter gives the Middle Fork permit requirements, safety information, and other information that we feel the prospective floater needs to know. The actual trip application lists first, second, and third choices for launch dates; names and experience of boatmen; number and types of boats to be used; a complete passenger list; a cost estimate and statement that the trip is private or noncommerical. The completed application must be returned to the Ranger District office. We try to limit reservations to one Middle Fork trip per summer per person. This is the reason for requiring a complete passenger list.

When the application is received it is date-stamped and given a number. The first working day in February our lottery is held. As a number is drawn, that application is pulled out and the applicant given his first choice of launch dates, if is not already taken. If all three of the desired launch dates are taken and the individual has not indicated that he will accept the closest available date, then he is notified that his requested dates were filled and he is invited to try again next year. If the applicant is successful in obtaining a launch date, a confirmation of the reservation is sent.

About the first of May, each suc-
ful applicant is contacted by mail to
rmine if they still plan to make the
le Fork trip and if they have had any
ces in their anticipated trip partic-
ts. After we get a response from these
ers and after the outfitter schedules
firmed up, additional reservations are
ed for the available launch dates to
ons on our waiting list.

The actual trip permit is not issued
il the launch date. The same trip per-
form is used for commercial as well as
commerical parties. A completed pas-
ger list, with addresses, is obtained
m the trip leader. Campsite assign-
ts are made for each night on the river.
special river hazards, safety warnings,
fire warnings are noted on the permit.
trip permit is extremely useful for
hering management and use data as well
for controlling use.

PERMIT PROBLEMS

There have been many problems en-
ntered in the Middle Fork permit system.
ermining river capacity is one of them.
the present time we estimate the capacity
the Middle Fork to be seven launches per
with maximum party size of 30 people
cluding boatmen) for commercial parties
15 people for noncommercial parties.
trip may take any time up to 10 days.
m our experience I would recommend that
h commercial and noncommercial parties
the same size. Whether the capacity of
iver is in number of people, number of
ties, number of user-days, or some other
tor, depends on individual river
itations.

We require reservations for only the
n floating season, but permits (obtained
the launch date) are required throughout
year. Limiting the capacity of the
er during periods of peak use tends to
ourage early season float trips which
se some safety problems with high water.
have yet to deny anyone a permit to
at the Middle Fork for safety reasons,
the Forest Service will advise prospec-
e floaters of river conditions, boatmen
lifications, adequacy of equipment, or
er safety factors.

Probably the biggest controversy on
Middle Fork management system at the present time is how permits should be allocated between the commercial and noncommercial parties. Past use was mostly commercial, but noncommercial use has increased rapidly. In 1976, it was necessary to turn down approximately 150 requests for private permits on the Middle Fork. At the same time the commercial outfitters did not fill up their allocation. There is no data or research available on which to base a percentage division between commercial and noncommercial trips.

A rigid permit system that assigns launching and campground dates allows little flexibility in your daily floating schedule. This rigidity detracts from the river trip and from the wilderness experience for all parties. Nevertheless, a fixed launch date is necessary for outfitters if they are to advertise and otherwise maintain a healthy, viable business.

People who show up without reservations and persons who make a reservation and then fail to show up both present problems. It is difficult to explain to the party from the east coast who has just driven 3,000 miles that they must have a permit to float a Wild River in the National Forest. We have partially solved this problem by allowing people without reservations to launch--provided the maximum capacity of seven parties per day has not been reached. This is the case many days out of the year due to no-shows in both the commercial and noncommercial sector.

ADVANTAGES OF THE MIDDLE FORK

There are some natural advantages that the Middle Fork of the Salmon River has that make the tight management possible. One is that the Middle Fork is entirely under the jurisdiction of one manager and one agency. The Forest Service has jurisdiction at all of the major access points. Launching from private land would be possible along the river, but this is not the established procedure, and at the present, constitutes a very minor portion of the use. There is a limited floating season on the Middle Fork of the Salmon. This allows the campsites to recover the rest of the time so they can maintain adequate vegetation for the short period of continual use. Other uses on the Middle Fork corridor are very limited. There is a minor but increasing amount of

backpacking. There is also some horseback riding, but mostly in connection with fall big game hunting. The majority of horseback riders only pass through the river corridor to the hunting area in the adjoining higher country. The very few oth activities makes the river management job much simpler.

REDUCING IMPACTS FROM RIVER RECREATION USERS

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ABSTRACT.--The dramatic increase in river usage makes it mandatory that managers utilize the latest knowledge in prevention of site degradation in order to maintain the desired experience. The manager must be constantly trying to utilize methods that prevent site deterioration. Often, through innovative management such as scheduling use, hardening sites, or improving human waste disposal, the manager can make it possible for a Wild and Scenic River Area to support more people without lowering the visitors' experience or the environmental quality.

Suddenly America's rivers are the place e. The number of users on some rivers doubled within recent years, and no level-off is seen in the trend. The river man- is given certain goals that the river the adjoining land should provide to best certain standards. A typical goal ement is: maintain the natural free flow- condition of the river; protect water lity; protect scenic, recreational, logic, fish and wildlife, and other ilar values; maintain the essentially itive shorelines; and provide recreation rtunities in harmony with the wild and ic nature of the river areas.

These are big orders for the manager to . In addition, in many cases, resource ification from past usage (buildings, roads, sion) must be restored to an essentially ural appearance. Although little research been done in reducing impacts of river reation, much work has been done in derness areas and developed recreational es that can be utilized in river management.

This paper is devoted to bringing together rmation that an administrator can use to the goals for a particular river.

REGULATING PUBLIC BEHAVIOR

Recreationists come to the forest to get y from the regimentation so prevalent in everyday world. However, there are many sons why they cannot be given free rein they visit the forest. The manager is faced with trying to protect the site from degradation, provide for the visitor's safety, and accommodate as many visitors as possible. Obviously, there has to be compromising of each to obtain overall goals.

The principle goal for Wild and Scenic Rivers is to protect the natural features of the area. Primitive resource-oriented recreation is a subordinate use that must be regulated to avoid detracting from the principle objective. The manager must seek to apply the minimum amount of necessary controls in an inconspicuous way once the visitor reaches his destination. Probably the most effective control is to separate the visitor from his vehicle as soon as possible to get him to travel on his own. This forces him to decide what is worth carrying and what should be left behind. Thus on his own he will usually leave behind gasoline lanterns that bake the cambium when hung on trees, radios that disturb other groups, firearms that endanger others, axes that are used to mutilate trees, and soft drink bottles that litter the landscape. This is part of the philosophy of the 1/4 mile corridor for Wild and Scenic Rivers. The abuse to the Chattooga Wild and Scenic River has been significantly reduced in the sections where visitors have been required to carry their equipment and boats into the corridor.

Visitors should be informed of regulations before starting their trip rather than encount-

ering signs during their trip. Regulations can be presented on a bulletin board at an entrance point, told by rangers who register the individual, or printed on the back of self-registration forms.

Lime and Stankey (1971) feel that the dissemination of information to the public is one of the most fruitful tools administrators can use to modify visitor behavior. By increasing contact with the public, managers can probably solve many current problems and help avoid others.

River Rangers are on duty at the three major access points along the Chattooga River. They ensure that all boaters use the required equipment and inform them of the best routes through rapids, what to do if trouble should develop, and how to dispose of litter. The results have been gratifying; the death toll on the Chattooga has dropped from 15 during a 2-year period to zero during the last 15 months.

Managers sometimes cause overuse of certain areas by the information they provide the public. If, for example, one portion of an area is overrun with people because the agency's publication features it on the cover, it may be well to feature some less impacted area that is harder to reach. Maps can be more detailed for areas where it is desirable to redistribute people away from more heavily used sections.

The number of boaters can be decreased by requiring certain skills and equipment before the user can participate. Because proficiency tests on the Chattooga River are not practical, all boaters on the most difficult section (4 miles) are required to use helmets. This often screens out the novice because few beginners own a whitewater helmet. Another method of reducing the number of persons using a particular area could be to require a permit for overused areas while no restrictions are placed on visitors using the less used areas.

Sometimes it is necessary to reduce one type of use to feature the use specified in the management plan. If hikers are utilizing most of the campsites on the only good whitewater river in the region, major foot travel routes should be relocated so as to bypass the most desirable campsites and eliminate the potential for conflict.

"Designation of a river as a unit of the Wild and Scenic River system can bring greatly increased visibility and populari with consequently rapid increases in visi ation. The resource has not changed that much, but is notoriety has, and popularit often increases abruptly" (Peters 1975)

Studies of wilderness users, which might also apply to river users (Stanke *et al.* 1974), suggest "a substantial per centage of them might find their desired experience more readily in a nonwildernes setting. It is likely that current press on wilderness stems from persons simply seeking a chance to hike or get away from the highly developed, civilized world for a short time".

CAMPSITE PROTECTION

The campsite is usually the river ar receiving the greatest abuse. Chief impa are soil compaction, erosion, and the elimination of vegetation. Research conducted in and experience derived from wil ness area management and lake areas desig ated for primitive travel can be utilized in river management because problems are similar.

Most site deterioration is caused by poor planning or administration on the pa of the agency. "The evidence indicates q conclusively that one of the principle reasons for widespread site degradation prevalent today has been lack of understanding by recreation planners and manag of vital resource of soil and soil relate factors in the overall site management picture" (James 1974).

The manager has two courses of actio concerning camping. First he can permit camping anywhere within the area, and second, he can permit camping only in developed or hardened sites.

Camping by boaters on some rivers is limited. Because of the rugged water on the Chattooga, the additional weight of camping gear makes a canoe very unresponsi so few people camp while canoeing. Regulations on the Chattooga allow both hikers and boaters to camp anywhere as long as th site is at least 1/4 mile from a road and at least 50 feet from a river, stream, or trail.

Where camping is a major activity, su as the Eleven Point River in Missouri and the Boundary Waters Canoe Area in Minnesot

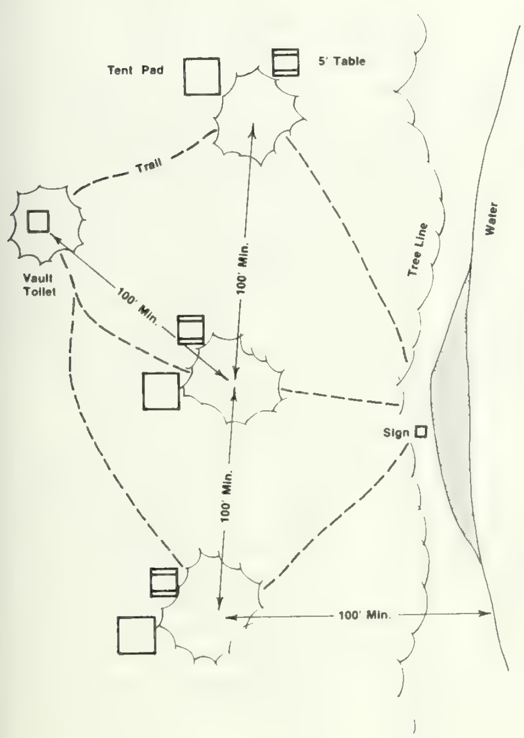
ping must be closely regulated. Campers the BWCA are discouraged from using eveloped campsites and forest officers uld contact and educate users of this icy.

Requiring visitors to stay in designated npsites is probably the only realistic ans of reducing resource damage when nping use is heavy. There are generally o to four camping units, as in the case the Sylvania Recreation Area in Michigan, each location, with a minimum spacing 100 feet between units (fig. 1). Little no brush removal between units is done provide a measure of privacy. Generally e camping unit is located at least 100 et from the water. Facilities usually nsist of a toilet, fire grill or ring, ace for up to three tents and sometimes wooden table. The fire enclosure is ovided to eliminate multiple fire spots d to reduce the chance of wildfire rather an as a convenience for the user.

Large groups are particularly hard on campsites when space is limited. They tend to cut down the screening between units to make room for more tents. This trend was well documented in a study in the BWCA (Merriam *et al.* 1974) that showed that newly cleared campsites nearly doubled in size in a 3-year period with use pressures from 320 to 900 cumulative visitor days (fig. 2). To minimize this site enlargement problem, the BWCA now limits each campsite to no more than 10 persons at a time.

Group size restrictions at the Sylvania Recreation Area on the Ottawa National Forest in Michigan limit each campsite to only one family or up to five persons per unit. If a larger group wants to use the area, they are required to split into smaller groups and camp and cook separately rather than gather at one site for meals.

It is far better to put money into initial planning, than to try to maintain



'igure 1.--*Typical Campsite for Boaters--Sylvania Recreation Area*

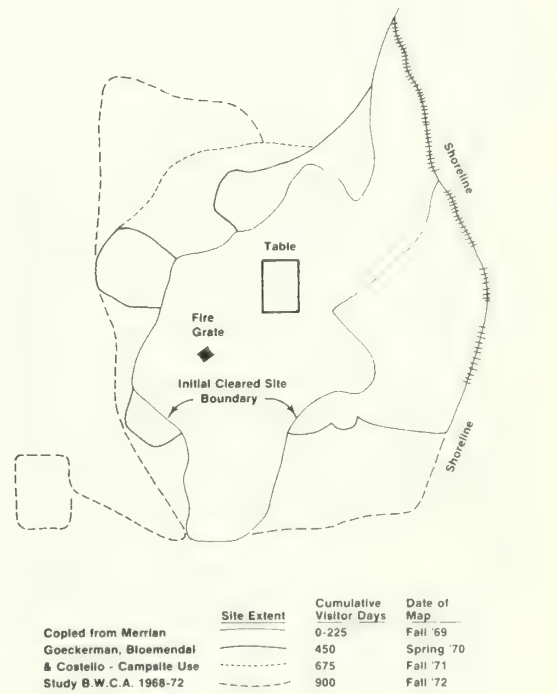


Figure 2.--*User Caused Expansion of a Boundary Waters Canoe Area Campsite*

a poorly selected site. The site selected should be above the high water line, have the best soil that will resist compaction, provide drainage for both camping and latrine, be fertile enough to support a lush growth of vegetation, have natural barriers such as rock walls or dense shrubs to impede site enlargement by visitors, and have a good landing area on water.

HUMAN WASTE

Public health laws often require that water used for recreation meet certain standards for biological purity. Heavy use by recreationists who fail to properly dispose of human waste can seriously degrade the water sources for both drinking and contact sports such as whitewater boating and swimming.

A wide variety of sanitation practices are used on our rivers and lakes ranging from ignoring the problems to constructing flush toilets. Decisions made depend on factors such as the number of users, funds available, ease of access, and agency goals.

Where the total number of users is not high, acceptable water quality can often be maintained by getting individuals to properly dispose of their waste.

Instructions in the use of the cat hole method can be printed on maps or given verbally. This is a single use pit covered with about 6 inches of earth. Management plans generally indicate that the cat hole should be no closer than 100 feet to the high water line, and studies have shown that decomposition is rapid.

Because of the heavy concentration of people, the BWCA uses a single seat toilet at many locations. This is simply a box with a hinged lid mounted over a pit. It is not surrounded by a building but is located in an area that provides vegetative screening. This minimal design standard was selected in an effort to reduce administrative costs and maintain a relatively pure experience (free from buildings). To protect water quality, BWCA standards require at least 48 inches of permeable soil below the pit and a minimum distance of 100 feet to a lake (BWCA 1969).

Pit privies are utilized in the majority of areas where structures are provided. If road access is not available, these privies can either be prefabricated and floated i pieces into the location or dropped in b helicopter.

Human waste may be causing biologic contamination or nutrient enrichment of water bodies. A study of nine sites and controls (Merriam *et al.* 1974) "found t recreation use of sites increased colifo bacteria and phosphate concentrations in the lake water at campsites to a point higher than public health standards allo for drinking water." Latrine location o lack of utilization of the latrine by use may be the cause.

A method to ensure that no human was enters water bodies from toilets is to bury a 300 to 1,000 gallon sealed vault below a privy type structure. This provi satisfactory collection of waste, but it be pumped out periodically. The only effective method of pumping is to use la trucks equipped with tanks and pump that be driven to the site. Adequate venting addition of biological odor control comp can usually prevent objectionable odors i the toilets.

The Sylvania Recreation Area put a number of 300 gallon vault toilets in isolated areas that could be reached onl by boat. When the vaults were full, the were emptied by hand pump into 55 gallon drums for transportation by boat to a roa The results were undesirable because grea difficulty was found in moving sewage. A remote 300 gallon vaults in the Sylvania Recreation Area have now been replaced wi 30 gallon above ground vaults. These sma holding tanks are slid into the back of t toilet under the seat. They can be used either in a manufactured fiberglass encl or in a modified Forest Service single se pit toilet building.

A 30 gallon holding tank will hold waste from about 500 visitor days of camp use and has a lid that can be sealed when full. When one is full, it is removed an an empty tank is then inserted into the toilet. Full tanks can be carried out by boat or stockpiled until the end of the season. A helicopter can be brought in t carry four of the full vaults per trip to road (Somerville 1976).

Recirculating toilets are used at so locations where odor control is difficult (high use areas, cool conditions that imp growth of odor controlling bacteria compo

se offer many of the advantages of a flush let system without the need for a ssurized water source or electricity. ever, to avoid expensive pumping, they uld be mounted over a holding vault because contents (70 gallons) of the toilet e to be emptied about every 1,000 flushes. resh charge of 15 gallons of water plus ouple quarts of chemical makes the toilet dy for another 1,000.

SOLID WASTE

The mess some recreationists leave be- d is staggering and creates a great impact resource managers. It is known to the lic as litter and to resource managers solid waste.

Studies have shown that river users ten consider that the presence of litter the low point of their trip and they put above other negative factors such as too ny people, obstructions to canoes, rowdy dividuals, or erosion (Solomon and nsen 1972). Because a large portion of ny managing agencies' budget goes into eaning up solid waste along waterways, warrants attention.

Obviously the best strategy from an ency's position is to get the recreation ers to carry as much of their trash as ssible. The "pack it in, pack it out" licy of the Eleven Point River assumes at if a person can carry a full container food in, he can easily carry out the pty cans and foil that can't be burned. e program is successful with 75 to 90 rcent of empty cans being removed Lefler 1976).

The BWCA provided plastic litter bags boaters for a number of years in an fort to increase the percentage of ntainers carried away from the area and rrectly disposed of. The bags helped, t because of the many uses, even the small rcentage of litter thrown into the shallow ter of the lake was excessive (Reid 1976). e BWCA now enforces a bottle and can licy where all "cans, bottles, and other od and beverage containers which are sposable but not burnable are prohibited." her containers such as insect repellent, el, toothpaste, etc., are permissible but pty containers must be removed from the ea by the user. Instead of cans, visitors st repack food in reusable plastic or tal containers. This policy has been successful in reducing litter cleanup costs and has had good acceptance with BWCA users.

Because it is hard to stop littering, a difficult cleanup problem exists at many areas. The majority of solid waste pickup responsibility falls on the managing agency. On the Chattooga River, ground crews pick up trash within about 1/2 mile of the river and carry it out by hand. The amount of trash beyond this point is usually much less concentrated because few visitors walk this far.

A lot of litter is also collected by nonagency personnel. Commercial outfitters run "pickup" trips down the river on days when no commercial trips are being run and the guides are still in pay status. Also, volunteer groups such as scouts, sportsmen, and outdoor groups may schedule cleanup trips in an effort to get their members involved.

On some very rugged rivers, wreakage of boats may be a major problem. After being wrapped around a rock or broken in two, these boats are often abandoned by their owners in disgust and can be difficult to remove from the river. On the Chattooga one private individual recovered 16 abandoned canoes in 1 summer. If his efforts to find the owner failed, he repaired and sold the canoes as his payment for the cleanup job.

MINIMIZING CONFLICTS THROUGH ZONING AND SCHEDULING

The managing agency must make the best use of the river and adjoining land to meet guidelines provided by legislative and agency policy. There will usually be many more special interest groups wanting to use the area than the land base will support.

The management plan must determine what uses will be permitted. To eliminate conflicting uses, only compatible interests can be permitted to be near one another. This gives the manager three choices: (1) noncompatible uses can be totally excluded, (2) the area can be zoned to permit different uses for portions of the area, or (3) incompatible uses can be scheduled when conflicts will be minimized. This calls for compromise.

Motorized vehicles are prohibited in wild sections of the Chattooga River corridor because areas for motorized use can be found easily in nearby locations. Different

portions of a river may be zoned for different uses. Fishermen may object to heavy boating use because it may interfere with fishing. The upper 30 miles of the Chattooga River are narrow and shallow, resulting in difficult boating conditions while providing the best cold water trout fishing in South Carolina. In contrast, the lower 28 miles of the river are too warm for optimum trout production, but offer some of the best boating in the eastern United States. So the USDA Forest Service closed the upper portion to all boating, and fishermen are told that they will encounter numerous boats when they fish in the lower portion of the river.

Conflicting uses can also be zoned so that one type of land use, such as horse trails, is permitted along one side of a river and another type, such as hiking, is permitted on the other side. Naturally the terrain, steepness, and soil suitability should play a major role in determining the zoning rather than simply continuing past usage.

Conflicting uses can be reduced by scheduling one when it will have minimum impact on the other. Outboard motor use is a long standing tradition by local groups on some rivers. If large numbers of canoeists begin floating the river, serious problems may develop because canoeists generally despise motor boats. It may be possible to work out a compromise if the primary use of motors is for gigging fish during the winter when there is little canoeing. Thus, the regulations might permit outboard motor use only from October 1 through March 31, thereby meeting the needs of both groups of users.

Scheduling daily departure times for river trips can reduce bunching up at difficult rapids. Commercial raft trips on the Chattooga are spaced at least an hour apart. This gives the clients an experience of boating in an uncrowded river and also makes it easier for faster-moving private kayaks to get around slower-moving raft flotillas. Limits can also be put on the number of trips commercial outfitters may make. Because most private boaters come to the Chattooga on weekends, the three commercial permittees are presently limited in the number of trips they can make on weekends.

Scheduling can also be used to give the campsites a rest. Campsites on the Middle Fork of the Salmon are assigned to boating groups with the objective of no more than one party using the site at one time and allowing the site to rest unused 4 out of every 10 days (Middle Fork Plan 1973).

Many Wild and Scenic Rivers have poor distribution of visitors. Some places are overused and others are underused. Ease of access largely determines where people will begin and end their trip. Managers can utilize the fact that many visitors try to minimize their contacts with other users. Maps showing areas of high recreat concentration may be useful in spreading the people out and therefore reducing the impact on the overused areas.

The areas near entry points often tak a beating because so many people are concentrated in them. On the Eleven Point River, no trail camps will be located withi a mile of any major road or trail head. This distance separates the majority of those who are just looking for a place to camp and those who are looking for the typ of experience offered in a Scenic River.

VEHICLE CONTROL

Motorized use such as 4 wheel drives or trail bikes may be determined to be incompatible with the management plan's objectives. However, especially in the cas of newly established Wild and Scenic Rivers use of motorized vehicles may already be well established, making it necessary to stop people from using vehicles in the area.

More than 60 closures of primitive roads were made to exclude vehicles from the Chattooga corridor. This action by the USDA Forest Service caused deep resentment among the people accustomed to driving in the area. To be successful, a major closure like this must be supported by publ document in the decision-making process, by informing the public of the regulations, and by effective law enforcement programs including publicity of convictions for violating orders.

Each road to be closed must be analyze to determine how serious an attempt will be made by off road vehicles to travel it. Ro with minor appeal to 4 wheel drives can be closed by felling a few trees across them, pushing a small (3 foot high) earth mound

rss the road with a bulldozer, or erecting
s barriers and signs.

Where a medium amount of effort is
pcted to breach the barrier, earth mounds
ank traps about 7 feet high are often
fctive in stopping vehicles if there is
ep terrain so the vehicle cannot drive
ndthe barrier. Finally, on roads where
eel drives are determined to come through,
eslope on either side of the road should
t least 50 percent and double mounds
t 10 feet tall should be pushed with a
e hole between them.

Gates stoutly built with enclosed locks
proved successful in stopping vehicles
he Chattooga. Much of this success is
ably due to the realization by the driver
he is destroying government property
ter than just winching his vehicle over
arth mound. However, on some gates,
saws have been used and it then becomes
essary to fill the pipe with reinforcing
and concrete.

All road closures must be backed up by
ropriate regulations prohibiting driving
losed roads and damage to government
erty. Closure signs are needed at each
tion and these need to be securely
ened. A method found to be effective
utting at least 8 largeheaded, long
k roofing nails in each 8 10" metal
and placing the signs high up on trees
hey cannot be pried off. Hopefully,
r a couple of years citizens will begin
ccept the closure and signs can be
cated to posts.

People who have traditionally used
roads resent being forced to walk to
river and seeing the river being used
and more by outside boaters. Examples
ow they take out their hostilities
lude starting forest fires, slashing
es, putting sugar in gas tanks of agency
icles, vandalizing signs and boaters'
icles, shooting across boats, and cutting
trees to block the river. Managers
ld begin comprehensive public relations
grams before closing roads and be ready
agressive fire suppression and law
orcement forces.

LANDING AREAS

Next to campsites, entry points or
dings receive the most concentrated use
are thus subject to serious degredation.
The ideal landing site has a gravel or solid rock surface at the water level on the inside bend of the river with a gentle slope up to an area suited for parking or camping. Steep bluffs should be avoided if possible because the heavy traffic will quickly eliminate the vegetation and erosion will begin.

In order to avoid more disturbance than necessary, people should be funneled from the parking area to the water's edge by barriers such as dense vegetation (either natural or planted), rocks, or logs. It may be necessary to reinforce unstable banks to prevent washing. In keeping with Wild and Scenic legislation, the more natural the appearance of this reinforcement the better. One method utilizes log cribs made with decay-resistant materials, and filled with coarse gravel, which can withstand both foot traffic and the river's current at the flood stage while blending well with natural features.

Campers tend to establish new landings closer to their unit instead of the central landing. Managers at lakeside campgrounds have had some success encouraging only a single landing by placing barriers to hinder boat access at some points and by adding a log or rocks so that a canoeist can enter a boat easier at a desired point.

RESTORATION

The river manager must have a good knowledge of how to revegetate and/or restore portions of his area. Restoration may be necessary because of changes in management philosophy such as closing roads to vehicles and making them less noticeable, or correcting overused areas.

Before successful restoration can be accomplished, the factors that caused the loss of vegetation must be removed. It is important to treat the problem, not the symptom. A manager's goal may be to screen improvements from a river. For example, if all the vegetation around the tables on the bank has been killed by picnickers, it is doubtful that the manager can restore the vegetation and still keep the tables. It is probable that compaction has eliminated some of the conditions that vegetation needs to grow. The tables should be moved to a site that has been hardened with gravel, or it can be located on bedrock where compaction will not be a factor. Water

eroding an abandoned road will probably continue even with grassing unless the road is drained with waterbars, outsloped, or ripp-rapped with stone.

An intimate working knowledge of conditions necessary for good growth of vegetation is also needed. Spreading seed to revegetate a site is often a waste of time and money unless proper amounts of fertilizer and lime are applied. The required rates can easily be determined by a soil sample. Compacted soils must be cultivated. If grass is to be sowed, it is very important to use the type of grass that meets the growing conditions on the site because each grass has different growth requirements.

Many rehabilitation attempts on campsites fail because managers do not realize that adequate amounts of sunlight must reach the ground for grass and tree reproduction to begin, thus it may be necessary to remove some of the shading overstory trees. Cordell *et al.* (1974) found that reducing canopy cover to 60 percent doubled grass cover produced under a 90 percent canopy and reducing canopy to 30 percent more than tripled grass production.

The additional cost and effort of mulching freshly seeded areas with hay or some of the woven mat materials is often justified, especially in sloping areas or areas with poor moisture capacity. In some dry areas irrigation may be the only way to establish a hearty vegetative mat. Because of the wide variation of the growing conditions of our nation, it is pointless to discuss the specifics in this paper. However, local county agents and Soil Conservation Service representatives are happy to work with managers seeking current information in this specialized area.

Because a natural appearing landscape is one of the chief reasons people seek our rivers and lakes, managers should strive to use nature or natural appearing plants in restoration work whenever possible. Nonnative plants such as Lespedeza and Multiflora Rose look out of place. In high visibility areas use of exotics is justified only if growing conditions are so severe that natural grasses and shrubs will not do the job.

If a manager cannot find commercial seed sources for plants he would like to use he may have to collect his own. Seeds fr fast-growing plants such as blackberries and poke berries can be quickly gathered, dried, and used to achieve the natural barriers needed for quality restoration projects.

Young plants and the tramp of people feet don't mix. When plants are becoming established, it is necessary to protect the area from traffic. Campsites should be closed for at least several years and foot trails relocated if possible. A lush growth of vegetation for several sea will be needed before the organic matter needed to resist the abuse of moderate human traffic will begin to build up in the soil.

Sometimes it is necessary to remove improvements on the land. The Chattooga Wild and Scenic River Management Plan required obliteration of portions of a campground and change in type of use from vehicle access to walk-in. The gravel on surfaced roads was loaded with a front end loader into dump trucks and spread on another road outside the corridor that needed gravel. This removal accomplished two jobs. First it resulted in a net saving of $2,500 for the road getting the gravel and second, it resulted in a much better job of revegetating on the old road that would not have been possible with gravel in place.

Facilities, such as 2,500-pound conc tables, that were located too close to th Chattooga were also removed. The decisio was made to move the tables intact. Loca residents may be extremely resentful of h their recreation facilities closed and fr a public relations standpoint, it may be worth the effort to try to salvage and mo improvements such as tables to another lo tion even if the cost is higher than dest tion of the old and construction of the n However, on the Chattooga, it turned out the concrete tables were moved from the r at a savings of more than $100 per table.

A restoration project is not somethi that can be forgotten after the work is done. The manager needs to keep checking to make sure the new vegetation is being protected and has the fertilizer and wate it needs.

DEVELOPING A RESEARCH CAPACITY IN FIELD ORGANIZATIONS TO AID IN MANAGEMENT DECISIONMAKING

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ABSTRACT.--Discusses (1) the trend toward developing research capacities in field organizations of national parks, recreation areas, or wildlife refuges, (2) factors that seem to be important in making that kind of a research capacity most useful, and (3) some implications for education in recreational management and planning. A detailed case history of the development of a river research program in one field location--Ozark National Scenic Riverways in Missouri--is given.

Today recreation managers--especially :iver areas--need an improved data base various reasons: increasing use of :eation areas, conflicts among users, : public scrutiny of management decisions challenges to decisions in courts of law.

It is becoming imperative for an in- ısing number of field units to have a ı base that goes beyond traditional ource inventory types of data, so they deal with new and undefined management omena. This calls for research-trained sonnel and the use of research methods.

This paper outlines various ways in which loor recreation resource management agencies ond to needs for research-based informa- ı. It is suggested that there has been ift from attempts to simply issue contracts research (the "purchase" model) toward eloping an "in-house" capacity to initiate evaluate research on field units (the ocess consultation" model). A case ly of one field research program at Ozark ional Scenic Riverways illustrates how ı a program evolves on a management unit.

WAYS TO OBTAIN NEEDED RESEARCH

Recreation resource management agencies have been getting research done for several years. There are 3 general ways to organize to obtain research data as the need increases:

1. Create central office planning-research units.
2. Create the traditional separate research units and management units.
3. Place researchers or research-trained personnel in field units, i.e., individual national parks, recreation areas, wildlife refuges, or equivalent management units.

An example of the first way would be the Research Section of the Long-Range Planning Division of the State of Illinois Department of Conservation. Three research- ers with Ph.D.'s (in economics, psychology, and wildlife biology) design and contract research for the Department. An example of the second way is the USDA Forest Service, which has followed the model of agricul- ture by using regional research experi-

ment stations. The third approach--emphasized in this paper--has been used by the National Park Service, which has tended to place researchers on individual parks as part of the management unit. In recent years, several other agencies (U.S. Fish and Wildlife Service, Tennessee Valley Authority, and some State agencies) appear to be following this latter pattern.

Managers have been faced with the need to determine recreational carrying capacity.[1] Such a determination is often complex (Wagar 1964 , Lime 1975a, Marnell 1976), localized in nature, and new to research. For these reasons, and because of the difficulty of obtaining research funds for field units, managers have tried various approaches to get the needed research done on their units.

One way this has been done is the approach of the Missouri State Parks System in the mid-1960's. The Director of State Parks initiated a grant of a few thousand dollars to the School of Forestry at the University of Missouri to support the new and developing area of recreation research. This tended to facilitate a series of discussions between university and State park personnel, but nothing very specific resulted. The State Parks subsequently switched to contracting for specific studies to be done. Another example is the arrangement worked out with the National Forests in Missouri and California, with the St. Louis County Parks Department, and with other field management units. In these cases a graduate student was employed as a summer employee or intern to work on specific research projects along with other duties.

Other units, e.g., Land Between the Lakes administered by the Tennessee Valley Authority in western Kentucky, have worked to develop "outside" funding sources, such as the Coleman Company, American Motorcycle Association, and American Honda, to support mutually beneficial research by university researchers.

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[1]*Data and insight for this paper come from the senior author's dual interests: (1) how land managers develop measures for determining recreational carrying capacity, and (2) how administrative organizations adapt to changing demands (Whyte 1969). Studies have been facilitated by offering the services of graduate students (who derive their theses).*

In the above examples, one common fact was the continuing dialogue with university researchers in recreation research rather than simply contracting for research. Sche (1969) has noted that the most prevalent model of consultation has been the "purchas of expert information or an expert service' This "purchase model" works well in establi fields, such as engineering, where the mana ment unit can clearly define a need and specify information needed. For less clear defined situations, he suggests the usefuln of a "process consultation" model. This model involves the managers and researchers in a period of joint diagnosis, to explore the relevance of various approaches to the complexity of the particular situation before initiating research.

Recreation field units are usually som distance from universities or other researc facilities. As the need for data on carryi capacity grows, there is a trend toward pla research-trained personnel in field units where they can act as a "process consultant a link between the managers and various kin of researchers. This utilization of a rese trained person to facilitate research effor has been tried (although with somewhat diff institutional arrangements) at 4 of 6 major recreation resource management units within 200 miles of Southern Illinois University.

A more important reason for the additi of research-trained people to recreation management field units is the relative newness of recreation research. In such compl matters as carrying capacity determination for large wildland areas, decision inputs are still being identified and methods of measurement are still being worked out. Thus it is often not feasible for a recreation management unit to simply contract for research services (as in the "purchase" model cited above). Rather it is necessary for research-trained individuals to work with managers on-site to develop a diagnosi of particular research needs, and then ofte to work with other research specialists to obtain research that is needed. Additional a research-trained person on a management unit can interpret the results of a researc project to managers and others, and help to implement the findings of contracted research.

What kind of a person should be recrui as "research-trained" for field level organ zations? How might that person be identifi

will such a person "fit in" to the existing nization? What kinds of adaptations in nizational operations will be necessary the researcher to function effectively? his recruitment analogous to the addition pecially trained persons for other nizational needs, such as engineers or itects?

Two observations might be offered about uitment. First, it is usually desirable ecruit someone who has conducted research, eceived part of his training, in the d. Second, it might be well to visit ous universities to learn which ones some fieldwork in their research ning.

The latter may stimulate university arch training programs into more aware- of field needs. It may also suggest arch opportunities, and the need for tional kinds of training. Specifically, ddition to continuing to improve research ning, it may be important for graduate ents to learn more about the complexity ield operations, and to gain a better eness of the nature of administrative nizations and the pressures involved in isionmaking.

VOLVING RESEARCH PROGRAM--A CASE HISTORY

At this point let us examine a research ram and study what has happened with the nization and the perceptions of the le involved.

One management unit that has initiated ield research program is Ozark National ic Riverways (ONSR), a National Park ice unit that has responsibility for inistering some 140 miles of the Current Jacks Fork Rivers in south central souri. Ozark National Scenic Riverways established in 1964 to become the ion's first Scenic Riverway. The area administered as a National Recreation a.

The area was set aside as a Scenic erway because of its many large and que springs which keep the rivers cold, ar, and moderately swift. It contains ssic examples of Ozark mountain scenery, the National Park Service maintains mples of native Ozark cultural activities interpretive programs. These character- ics, plus its proximity to St. Louis, Missouri (about 150 miles), make the area a favorite for canoeists. From relatively few canoe float trips in 1964, floater use had increased to approximately 150,000 floater days in 1974 (Wehrung 1975). Some sections have become quite congested with canoes, especially on summer weekends.

In October 1971, an aquatic biologist was added to the ONSR staff. He had previously worked at Yellowstone and Yosemite National Parks. His assignment was to evaluate the status of the river fishery, which had long upheld an outstanding reputation but was claimed to be declining. Shortly after his arrival, however, the biologist sensed that a crisis was forming in connnection with the exploding popularity of canoe floating at the Riverways. Concerns about the fishery diminished as attention focused on river use.

The biologist recommended a comprehensive research program dealing with this matter to the ONSR Superintendent and this was concurred with--even though it would take several years, and almost no research funds were available.

By July 10, 1975, the National Park Service summarized the six approaches of the River Use Research Program at Ozark National Scenic Riverways as follows:

1. *River-Traffic Investigations*--These document the volume, composition, and distribution of river-traffic; access use; float trip patterns; floater camping trends, etc. The program relies on remote sensing technologies, survey data, and computer analyses.

2. *Floater Impact Evaluation*--Evaluates environmental impacts associated with use along the river corridor. Problems of erosion, soil compaction, vegetation response, etc., are being investigated.

3. *Sociological Aspects of River Use at ONSR*--A series of studies that yield information on floater attitudes and perceptions, i.e., effects of crowding, float group structure, user-group conflicts, etc. The data is gathered through the use of OMB-approved questionnaires. The studies are available in thesis form.

4. *Safety Evaluation of River Use at ONSR*--Emphasizes the heavy-use access points and critical enroute areas along the river.

5. *Water Quality of Current and Jacks Fork Rivers*--A baseline study for future monitoring of water quality. Correlation of water quality with river use is included as a study objective.

6. *Economic Impacts of ONSR*--A study to evaluate the impact of ONSR and recreational floating on local and regional economies.

Reports for most projects are to be completed by December, 1975. A Summary Report prepared by the NPS will be available by December, 1976. This will include findings and recommendations of all projects completed to date. This report will be fact-finding only and will *not* constitute a River Use Management Plan.

A formal River Use Management Plan will be developed following the opportunity for public input and a review of various alternatives. No data can be given for implementation of a River Use Management Plan since this will ultimately be contingent upon an approved Master Plan, fulfillment of NEPA requirements to support the plan, and the followup process of additional public review.

The evolution of the research program is much more complex than is indicated by the above summary. It is worth noting that the biologist's role shifted from researcher to research coordinator to information disseminator. It might be well at this point to examine the perceptions of participants in terms of what has taken place.

The Agency Researcher's Perspective

After securing approval to embark upon a river use research program at Ozark National Scenic Riverways (rather than "stock fish"), the agency researcher proceeded by (1) identifying specific problems, (2) immediately starting research in several disciplines, including some outside his own speciality, and (3) making contact with "outside" researchers to gain from their expertise and to encourage their involvement in the research program at ONSR.

Identification of research needs began with concerns about the lack of information on several basic aspects of the problem. Aside from environmental matters, questions were raised about river users, their motivations, and their perceptions about ONSR. The identification of program needs evolved into a dynamic process, constantly being revised as new inputs became available, or as demands for new information arose.

Research outside the agency researcher's specialization focused first on the problem of determining how many canoes were floating the Riverways. It was known only that there were "a lot" and that the numbers were increasing each year. The researcher, with a background in electronics, responded by developing a sophisticated low cost monitoring system for accurately measuring numbers of floaters (Marnell 1975). This was later expanded into a complex program involving several techniques to yield data on a broad range of use-parameters.

Contact with "outside" investigators began with university researchers who had previously conducted studies in the area, or had otherwise expressed an interest in lending assistance. The agency researcher also met with State Conservation Department personnel to learn of their experience in the area prior to its designation for Federal management. Followup on these meetings and attendance at various research conferences produced new information and additional contacts. As funding became available to support the research program, it was applied first to studies where special equipment and laboratory process was required (i.e., water quality investigations). Funding was later diverted to graduate student projects.

As the research program developed, two unforeseen demands began to draw on the agency researcher's time; (1) more time was needed for administration and overall coordination of research activities, and (2) requests were being made more frequently for presentation of research findings. There were many frustrations involved in research contracting and in securing administrative clearances (i.e., "red tape" for approval of survey questionnaires, etc.). Also, the task of locating and arranging for the services of people possessing certain skills, often with only limited funds available, required a rather personal involvement at times by the field scientist. Requests for presentations of findings ranged from "in-house" briefings for supervisors and associates to appearances before local

ic groups such as Rotary Clubs, Chambers Commerce, etc. There have also been reasing requests for presentations at ional and national meetings, such as s one. These are seen as opportunities constructive discussion and the rning of new ideas.

What effects have these role changes had the agency researcher? A few peers have n somewhat skeptical, as though he had ected from the "purity" of his discipline. ever, this has been largely offset by mulating and productive associations with earchers in a variety of disciplines. example, recreation researchers interested carrying capacity determination have ome interested in the scope and complexity the program at ONSR.

Perhaps the main reward for the field earcher in this type of situation is the ling of having made a contribution to decisionmaking process.

Whatever the outcome may be on the river issue at ONSR, the agency and the general lic will at least have the benefit of a stantial information base to work from.

The Area Manager's Perspective

The field biologist position was ablished at Ozark National Scenic River- s (NSR) to accomplish rather specific tasks. position was assigned as a staff type job orting directly to management but having tine contacts with all other staff as well line personnel.

The area manager had earlier experience king with researchers such as historians archeologists, plus professionals in fields of engineering, landscape hitecture, and architecture. It had been observation that few problems are encountered "fitting in" a researcher or professional o a field management organization. However, ack of appreciation and understanding of agement needs and pressures more often occurs.

After a short period of orientation on part of both the researcher and manager Ozark NSR, it became evident that pressures to manage the rapidly increasing river use greatly outweighed the concern for fishing conditions.

As the researcher developed his study program along with a work accomplishment schedule, time became critical. It was necessary to place a moratorium on all commercial river use operations in order to limit increases during the study period.

Pressures have been increasing annually to effect changes in that moratorium, and these have ranged from political to court action. Support for the interim management position also has been substantial, and has included Congressional backing.

A comprehensive research program was required to provide the necessary data for the purpose of developing a management plan for the protection and use of the Ozark National Scenic Riverways. A firm position on interim management controls was mandatory to provide an adequate fact-finding period.

CONCLUSIONS

All three ways of gathering research data for recreation management (1) central office planning-research units; (2) experiment stations established by the managing agency; (3) placement of researchers or research-trained personnel in field units,continue to be important. However, there is a trend toward supplementing the first two ways with the third in the lower Midwest and the upper South.

Instituting an effective research program--such as the one described in the case history--takes time. Do not expect "overnight" results. As with adding other specialized persons (such as landscape architects or engineers) to field management staffs, it will take time for a researcher to learn about the area, make necessary contacts with supporting persons, and to collect and analyze research data. The case history research program at Ozark National Scenic Riverways has been operating for 4 years. If you foresee research needs on your management unit, the time to think about implementing research is now rather than under "crisis" conditions.

RIVER-RUNNING IN THE GRAND CANYON: HOW MUCH AND WHAT KIND OF USE[1]

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ABSTRACT.--Management issues relating to amount and kind of river-running use on the Colorado River in the Grand Canyon were investigated. Results show that use levels affect number of inter-group contacts, but number of contacts has little effect on perceived crowding or user satisfaction. Probable effects of an increase in commerical and/or private oar trips are described.

Colorado River trips through the Grand Canyon take from 5-11 days by motor (on 30-40 foot pontoon rafts) and from 12-18 days via oar boats, which are generally smaller (15-25 feet) crafts. Stops are made at places of scientific, historical, esthetic or recreational interest. At night, trip members camp on natural beaches along the river. River trips in the Grand Canyon can be categorized on two dimensions. They are either *commercial*--i.e., run by outfitters who are in the business--or *private* --that is, organized by individuals on a nonprofit basis. Trips can also be characterized as *motor* (75 percent of all trips) or *oar* powered (25 percent).

The Issues

Dramatic increase in use for river-running on the Colorado River in the Grand Canyon (and elsewhere) has precipitated the need for research on three management issues. The first has to do with how muc use is compatible with a quality wilderne recreation experience. The question is: What density levels can be tolerated befo an area becomes "too crowded" and no longe a satisfactory wilderness experience? Ho many is "too many" people? What, in shor is the sociological carrying capacity of the area?

This issue has received the most attention and much of the literature reflec a "user satisfaction" model. Specificall it is assumed that density or use levels will increase the probability of contacts with other groups: that as contacts increase, users are more likely to perceive that area as crowded, and that this perception will, in turn, have a negative effect on how they define their experienc (For a review of this literature, see Nielsen, Shelby, and Haas 1977). It is expected, of course, that there are differences among users in their perception of and reaction to crowding. Wilderness "purists," for example, have been identif as those who share a pro-wilderness ideology and are expected to be more sensiti

[1]*The research reported in this paper was conducted under Contract CX 821040104 between the National Park Service, Grand Canyon, Arizona, and Human Ecology Research Services, Inc., Boulder, Colorado, 80302. Any opinions, findings, conclusions, or recommendations expressed in this paper are those of the authors and do not necessarily reflect those of the National Park Service.*

o crowding than nonpurists (Stankey 1972 , endee *et al.* 1968).

While the carrying capacity issue is alient for all wilderness recreation acivities, two additional issues regarding *ind* of use are more specific to river unning. One is what we call the "motorar" issue. This is essentially the uestion of whether motor travel should be hased out--a policy alternative based rimarily on the argument that motor travel s inconsistent with a wilderness experence. Arguments in favor of motor trips ocus on their ability to provide a riverunning experience for more people in ess time. A second issue has to do with he current unequal distribution of useray allotments between the private (8 ercent) and commercial (92 percent) ectors. Very simply, private users want greater share of total user days per eason.

PREVIOUS RELEVANT RESEARCH

Research on these two issues is scanty. ifferences between motor boaters and canoests in the Boundary Waters Canoe Area of orthern Minnesota have been researched by ucas (1964b, 1964c), who found that canoests disliked meeting motor boats. Motorsts, in contrast, were not bothered by conacts of either kind.

PROCEDURE

Data relevant to these issues were genrated by having participant observers acompany a stratified random sample of trips uring the summer 1975. Trips were stratfied on the basis of seasonal use patterns; hat is, more trips during high use and ewer trips during low use periods were seected. Private trips were oversampled so hat a separate comparison between them and ommercial trips could be made. The total ample, consisted of 46 commercial trips 39 motor and 7 oar) and 7 private trips.

Observers recorded number and kind of ontacts (i.e., whether they were on the iver or at attraction sites along the iver), kind of trip with which contacts ere made (whether motor or oar, private r commercial, etc.), the kind of interction that ensued (if any) between the parties, and overall reaction to seeing another boat or group.

Observers also kept a trip itinerary and recorded quality and quantity of intragroup interaction. They also recorded "adjustments for crowding" made by the boatman. These occurred whenever trips went farther or faster than planned, slowed down, changed the location of a planned campsite, or passed up attraction sites because of the presence of others.

On the last night of the trip, passengers completed questionnaires designed to measure background variables (e.g., age, sex, socioeconomic status, rural or urban residence, outdoor recreation experience), wilderness values, expectations about the trip, perceived crowding, subjective knowledge (how much you think you learned), objective knowledge of the Canyon, perceived social benefits of the trip, other evaluative dimensions of the trip, and preferences regarding kind and number of contacts. Multiple-item scales were constructed for most of the attitude and value variables. A total of 1,009 questionnaires, representing a 96 percent response rate, were completed.

To provide a methodologically valid comparison between the motor and oar experience, four experimental trips were arranged. Twice during the season, two trips (one motor and one oar) were scheduled to leave Lee's Ferry so that they would meet halfway through the Canyon. At this point, passengers on the oar boats switched to the motor boats and those on the motor boat switched to oars for the remainder of the trip. The 56 passengers on these trips filled out a modified questionnaire after the first half of the trip and the standard questionnaire at the end of the trip. Other data collection procedures used on these experimental trips were similar to those used for standard trips.

National Park Service records also were obtained to measure use or density levels. Use level was defined as the total number of people or trips leaving Lee's Ferry three days before and after a trip's departure date. Thus density can be measured in terms of people or trips per week; use levels ranged from 80 to 940 people and 13 to 32 trip per week. As might be expected, the correlation between these two measures was high (r=0.94).

RESULTS

Passenger Characteristics

Like other wilderness recreationists, commercial river travelers in the Grand Canyon (n=849) are a fairly select socio-economic group. Income levels are high; half reporting family incomes over $24,000. Educational level is also high; 78 percent had attended college, of which 53 percent had earned a bachelor's or advanced degree. The average age is 33: 43 percent are married; and the two sexes are equally represented; 64 percent live in large cities or suburban areas. Only 22 percent belong to an outdoor club or conservation organization; 31 percent were on their first wilderness-type trip.

Sociological Carrying Capacity

As expected, probability of contact increases with use level as shown in the tabulation below.

Variable	*Correlation with use level (People per week)*
Trips per week	0.94
River Encounters	
Contacts per day	.68
Time in sight (minutes)	.47
People per day	.65
Attraction Site Encounters	
Percent of sites (total) with contact	.58
Probability of meeting another trip at:	
Little Colorado River	[2].28
Elves' Chasm	.69
Deer Creek	.43
Havasu Creek	[2].31
All four sites	.58
Number of people met at:	
Little Colorado River	[2].25
Elves' Chasm	.43
Deer Creek	[2].26
Havasu Creek	[2].33
All four sites	.51

Thus, the first part of the carrying capacity model is confirmed.

The tabulation below, however, shows that there was no relation between contacts on the river and perceived crowding (r=0.0 and a statistically significant but low correlation (r=0.12, p<0.01) between attraction site contacts and perceived crowding.

Use or contact variable	*Correlation with perception of crowding*
People per week leaving Lee's Ferry	0.05
River contacts per day	.05
People per day seen on river	.05
Time in sight of people on river	.03
Percent of attraction sites (total) with contact	[3].12
Average number of people seen at attraction sites	[3].13

Correlations between number of contact and perceived crowding were not significantly different for respondents who measured high on several indicators of wilderness values.

The tabulation below shows that the correlation between perceived crowding and satisfaction is statistically significant and in the right direction (that is, those who perceived crowding showed less satisfaction), but not large enough to be substantively important (r=0.14, p<0.01).

Variable	*Correlation with overall trip rating*
Perceived crowding	[3]0.14
People per week leaving Lee's Ferry	.00
River contacts per day	.05
People per day seen on river	.03
Time in sight of people on river	[3].10
Percent of attraction sites (total) with contact	-.01
Average number of people seen at attraction sites	.02

In sum, the data provide only partial confirmation of the user satisfaction carrying capacity model. Use is positively correlated with contacts but contacts show little relation to perceived crowding, and perceived crowding seems to have little to do with user satisfaction.

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[2] *$p<0.05$. All other probabilities are less than 0.01.*

[3] *$p<0.01$.*

Explanations for the lack of empirical confirmation of the carrying capacity model seem to fall into two categories: (1) those that assume the model is incorrect; and (2) those that assume the model is correct, but that for various reasons data from the present study don't support it. Those in category 2, for example, argue that current density levels are simply not high enough to affect the user's experience. A higher use level (e.g., over a thousand people leaving Lee's Ferry per week rather than the current average of 660, and seeing 100 people from other trips per day rather than the current average of 72) might show a significant effect on perception of crowding, which would translate into a negative experience by the user.

A second explanation is that the relations specified in the model will hold, but not for the population we tested. It has been suggested, for example, that those likely to be sensitive to crowding (and therefore show a negative reaction to higher use) have already reacted by going elsewhere--i.e. to less crowded places. This is referred to as the displacement phenomenon, meaning that more sensitive users have been displaced by less sensitive ones. It is consistent with the fact that this was the first river trip (62 percent) and the first time in the Canyon (90 percent) for a large proportion of the population.

The high percentage of first-time users in the river-running population sampled suggests another explanation for lack of empirical support of the model, but in this case the model is considered incorrect. It may be that the carrying capacity model assumed too much. That is, one must be aware of a norm or standard about crowding in the wilderness before one can define it as having been violated. The lack of empirical supportive data for the model may be due simply to the fact that current users have no specific expectation or norms about what is an appropriate contact level. More than half of the respondents did not know what to expect in terms of river contacts, and a third had no expectation regarding the number of people they anticipated seeing relative to the number actually seen.

The carrying capacity model may be incorrect in another way. Perceived crowding is only one of many variables that might reasonably affect the quality of a trip. This is supported with data shown in the tabulation below, which lists trip features that were related to user satisfaction.

Variable	*Correlation with trip rating*[3]
Personal Benefits	
Subjective Learning	0.31
Personal Growth	.19
Social Aspects	
Quality of Group Experience (subjective)	.32
Accessabilty of Boatmen	.32
Rating of Boatmen	.37
Passenger Role was Unambiguous	.28
Wilderness Character of the Experience	
Being in wilderness an important reason for trip	.20
Pace of trip perceived as leisurely	.29
Evaluation of trip as a "nature experience"	.31
Trip perceived as "noisy"	-.24
Use impact perceived as high	-.20
Would prefer more conveniences	-.29
Other	
Weather perceived as bad	-.22
Was unprepared for trip	-.22

In short, a multivariate user satisfaction model is more consistent with our findings, and the traditional model seems to be oversimplified.

In addition, there is the effect of the Canyon itself to consider. The Canyon is a spectacular natural phenomenon, and seeing it from the river is in many respects a unique experience. It may be that this singularity overshadows the effect of other trip features (e.g., contact with other trips) and makes them seem trivial or minor in comparison. (We do know, of course, that some variables are not completely overshadowed by the physical setting).

The traditional carrying model may be incomplete in another way. Research on density and crowding effects in other areas (e.g., urban settings, dwelling places, public settings, etc.) suggests that people respond to increased density with a variety of adjustment mechanisms that decrease the

probability of undesirable contacts. The assumption is that stress or other forms of malcontent are thereby avoided. Something similar may be happening on the river. If adjustments for crowding are made as use levels increase (as shown in table 1), some kinds of contacts may be avoided. Table 1 shows that number of changes in plans per day is related to density, whether measured by number of trips leaving Lee's Ferry or by number of river contacts per day. Likewise, the total number of sites visited is negatively related to these two use measures. These relations hold for both motor and oar trips, which indicates that the adjustments-use relation is not dependent on travel model. It may be that crowding adjustments are keeping certain types of contacts to a minimum--for example, those at campsites. This would keep total contacts down, thereby reducing the potential effect of increased use levels. The relation between density and adjustments for crowding, of course, does not explain the lack of relation between contacts and perceived crowding or that between perceived crowding and user satisfaction.

higher use levels will probably have little effect on satisfaction. Overall, data from this study suggest that managing for user satisfaction (i.e., with the carrying capacity model in mind) means an increase in use level. Indeed, if one did build a tram in the Canyon (a possibility we asked passengers to respond to), one could certainly increase the number of people served. And it's likely that they would evaluate their experience as a positive one. Such a policy, however, would drastically change the character of the river-running experience.

In the case of the Grand Conyon, for example, there is considerable evidence that both passengers and managers define the area and river-running experience as a wilderness one. The vast majority of river travelers defined their trip as a wilderness experience. Ninety-one percent agreed that they would consider the area "wilderness". Most people (65 percent) preferred two or less river contacts per day (low use), and almost all (90 percent) preferred to camp away from others. Furthermore, people generally viewed the

Table 1.--*Correlations of use levels with adjustments for crowding*

Variable	Use level (Lee's Ferry)	Correlation with: Down river use level (river contacts per day)	Down river use level controlling for propulsion
Changes in plans per day (No.)	0.23	[1]0.47	[1]0.44
Sites visited (No.)	-.12	[1]-.42	[1]-.30
Average length of stops at sites	-.12	[1]-.29	-.13

[1]$p<0.05$.

While this discussion has been rather theoretical, there are policy reasons for ascertaining the accuracy of the carrying capacity model. If the model is correct, but empirically not confirmed because of less than effective use levels, carrying capacity based on user satisfaction will eventually be reached when use increases. If the model is correct, but not empirically confirmed because of particular characteristics of the population tested, use increases will have little effect on users' evaluations of river trips in the Grand Canyon. Use levels could probably exceed an average of 56 trips per week, which would result in 9 or 10 contacts per day and aggregate user satisfaction would continue to increase. Likewise, if the model is either too simplistic or incomplete,

Canyon as a place where developments and conveniences are out of place. Only 10 percent felt there should be more developments like Phantom Ranch, and only 7 percent favored building a tram into the Canyon. A similarly small number favored more conveniences (9 percent) and better facilities (12 percent) on river trips.

To the extent that wilderness recreation is associated with low use and few contacts, then higher use levels will change its character. People will still have a "good time" but they will no longer define it as a wilderness one. The question is whether managing for satisfaction is the most reasonable strategy for wilderness recreation. From a management perspective, it might make more sense to define the

:ind or character of the experience one vants to offer and choose a use level that .s consistent with it.

Motors and Oars

Table 2 shows that there are few background differences between passengers on the standard trips. The only statistically significant differences are that those on motor trips show slightly lower education and occupational prestige levels. With respect to past or other outdoor experience and artifactualism (endorsement of development of wilderness areas), the motor trip passengers are less likely to participate in outdoor clubs and activities and more likley to favor development. Except for the former, however, none of these differences is very large. In short, motor and oar passengers show little differences in what can be described as pre-trip characteristics. As a result, a change in the proportion of motor and oar trips would probably have little effect on the composition of the river-running population in general.

What about the features of the trip itself? Motor and oar trips differ in a number of important respects, as shown in table 3. Motor trips are slightly larger, have more people per boat, have more contact with other parties each day but fewer contacts per trip, spend less time in the Canyon, make fewer and shorter side stops, and make more adjustments for crowding per day. Partly because oar trips are about twice as long as motor trips (14 days compared to 7 days), more stops are made (17 for oar versus 12 for motor) and the time spent at these sites is much longer (6 hours versus 1-1/2 hours).

These differences in kind of experience associated with an oar or motor trip (in spite of few pre-trip differences) seem to be reflected in attitudes and opinions about the trip itself. Like Lucas, we found that most oar trip passengers (92 percent) preferred to meet other oar trips on the river. Among those on motor trips, in contrast, 18 percent preferred to meet oar trips, and 9 percent motor trips; 73 percent said it made no difference. People on oar trips were also more likely to describe motors and their noise as inappropriate. In response to the question, "Does outboard motor noise bother you?" 94 percent said "yes"; only 18 percent (127) of those on motor trips said "yes".

Those on oar trips preferred fewer contacts on the river. More than half (54

Table 2.--*Background characteristics of passengers on standard and combination trips*

Variable	Correlation[1] with trip type	Mean value[2] Standard trips	Combination trips	t Value
Demographic Characteristics				
Age	-.05	32.8	30.9	1.0
Sex[3]	.01	1.48	1.54	.6
Education	-.14*	13.2	13.9	1.1
Occupational status	-.12*	5.3	5.5	.7
Income	.09	7.4	7.7	.6
Marital status	.01	2.4	2.2	1.7
Number of children	.08	1.1	1.0	.2
Present residence (rural-urban)	.03	3.7	3.6	.9
Past residence	.00	3.4	3.3	.8
Outdoor Experience and Attitudes				
Membership in outdoor club or organization[4]	-.20*	1.2	1.2	.3
Time of first wilderness experience	-.06	3.3	3.5	.8
Experience on other rivers	-.02	1.6	1.9	2.4
Participation in outdoor activities	-.10*	11.5	11.3	.5
Artifactualism	.16*	12.4	9.4	5.2*

[1]Standard (commercial) trips only; coded 1 = oar, 2 = motor

[2]All means except those for age and number of children are based on coding categories and are by themselves meaningful only for comparison purposes.

[3]Coded 1 = male, 2 = female

[4]Coded 1 = no, 2 = yes

*p<.001

Table 3.--*Comparison of characteristics of motor and oar trips (commercial trips only)*

	Mean (average) value: Oar	Mean (average) value: Motor	t Value
Party (No.)	24.1	29.8	1.7*
Boats (No.)	5.1	2.0	5.5
People per boat (No.)	4.8	15.2	15.7
River contacts per day (No.)	2.2	3.8	2.9
River contacts (total no. per trip)	36.5	23.4	2.8
People seen per day (No.)	44.3	80.9	2.8
Boats seen per day (No.)	5.4	9.7	2.6
Minutes (per day) in sight of other parties	28.3	41.0	1.3*
Average length of contacts (minutes)	14.1	10.2	2.0
Length of trip (days)	14.4	7.3	6.0
Total number of attraction sites visited	17.0	12.1	2.3
Average length of stops at sites (hours)	6.0	1.3	2.4
Adjustments per day for crowding (No.)	.23	.43	1.6*

*$p<0.10$. For all other differences, $p<0.05$.

percent) wanted to see no other parties, 27 percent preferred 1 or 2, and only 19 percent preferred three or more contacts each day. In the motor group, only 38 percent preferred no contacts, 28 percent preferred 1 or 2, and 34 percent would have liked to see three or more parties each day.

Combination trip passengers showed a rather clear preference for thé oar trip. As seen in table 4, 79 to 91 percent chose oar trips compared to the 4 to 6 percent who preferred motor trips. The most frequent reason given for this preference were that oar trips are slower, more natural, and the social interaction (in smaller groups) more satisfactory. These data indicate that the oar trip is seen as more consistent with a wilderness experience.

Since there is some controversy over the relative safety of motor and oar trips, combination trip passengers were asked to indicate which mode of travel they thought was safer: 26 percent considered the oar trip safer, 26 percent thought the motor safer, and 48 percent felt there was no difference.

Since the number of combination trip passengers was small--at least for purposes of generalizing to a larger population--it was important to know whether they differed substantially from other commercial passengers on pre-trip variables. Columns 2 and 3 of table 2 show that they differed little from standard trip passengers in terms of demographic variables and artifactualism (attitude toward development in the Canyon). However, to the extent that trips vary by outfitter, results based on these 4 combination trips (which were run by one of the over 20 different outfitters currently running the Colorado-Grand Canyon) may not generalize to trips run by other outfitters.

These findings have important implications for management alternatives regarding the proportion of motor and oar trips. While an "oars only" policy would not drastically change the composition of the population, it would mean smaller parties, and more boats per trip, thus

Table 4.--*Motor-oar preferences combination trips*

	Oar	Motor	Makes no Difference	Total	Missing Observations
If you were planning a trip on another river, which type of trip would you choose?	87% (46)	4% (2)	9% (5)	100% (53)	(3)
Which would you recommend to a friend planning a Grand Canyon trip?	79% (42)	6% (3)	14% (8)	100% (53)	(3)
Which type of trip better enabled you to "experience" the Grand Canyon?	91% (50)	5% (3)	4% (2)	100% (55)	(1)
Overall, which type of trip did you like better?	82% (45)	5% (3)	13% (7)	100% (55)	(1)
Which do you think was safer?	26% (14)	26% (14)	48% (26)	100% (54)	(2)

occupying more space on the river. Con-
tacts per day would be fewer but total
trip contacts would increase. It's prob-
able that time in sight of other parties
would be greater because oars have less
ability to vary their speed, and can't pass
other boats as easily. Trips in general
would be longer and fewer people per sea-
son would run the Canyon if user days were
held to their present limit. There would
probably be more congregation at attraction
sites insofar as oar trips stay longer and
stop at more sites. Finally, oar trips
show fewer adjustments for crowding--again
partly because of their less variable
speeds. In short, an increase in oar
trips and decrease in motor trips would
mean changes in downriver contacts. This
suggests new but not necessarily more or
less solvable contact problems.

People who had either a motor or oar experience tended to endorse the kind of experience they had, though oar passengers seem more supportive of oar trips than motor passengers were of motor trips. This suggests that preferences and norms about contacts and crowding are established during rather than before the trip (for most passengers, at any rate).

Private and Commercial Trips

Private users are slightly younger and more predominately male (table 5). They report slightly lower incomes and are less likely to live in cities. They are more likely to belong to outdoor clubs, and to report having had their first wilderness experience earlier. They have had more experience running other rivers, and are more likely to have been down the Grand Canyon before. They also participated more frequently in other outdoor activities, such as camping and backpacking. The largest background differences between the private and commercial groups exist on the outdoor experience variables, particularly experience running other rivers. Furthermore, except for income and membership in outdoor clubs and organizations, these differences remain when controlling on the motor-oar dimension. This means that the background differences between private and commercial trips are not explained by the fact that private trips are primarily oar. When comparing commercial and private oar passengers within the motor and oar categories, the differences between them remain. In short, an increase in private users would mean some changes in the composition of the river-running population. Specifically, it would increase the number of experienced and seasoned river-runners as opposed to first-time users.

Private trips have fewer people, more boats, and less people per boat than the average commercial trip (table 6). They

Table 5.--*Background characteristics of private and commercial river runners*

Variable	Correlation with trip type (commercial-private)[1]	Correlation with propulsion (oar-motor)[2]	Correlation with trip type controlling for propulsion
Demographic Characteristics			
Age	-.12*	.01	-.12*
Sex[3]	-.16*	.07	-.13*
Education	.00	-.10	-.07
Occupational status	-.05	-.07	-.10
Income	-.17*	.13*	-.09
Marital status	-.08	.05	-.05
Number of children	-.04	.07	.02
Present residence (rural-urban)	-.23*	.11*	-.17*
Past residence	-.09	.03	-.07
Outdoor Experience and Attitudes			
Membership in outdoor club or organization[4]	.26*	-.25*	.10
Time of first wilderness experience	.22*	-.13*	.15*
Experience on other rivers	.57*	-.25*	.48*
Experience in Grand Canyon	.23*	-.11*	.17*
Participation in outdoor activities	.34*	-.21*	.22*
Artifactualism	-.08	.15*	.03

[1] Coded 1 = commercial, 2 = private
[2] Coded 1 = oar, 2 = motor
[3] Coded 1 = male, 2 = female
[4] Coded 1 = no, 2 = yes
*$p < .001$

Table 6.--*Comparison of characteristics of private and commercial trips* (With separate means for commercial motor and oar trips)

Variable	Mean (average) Values			
	All	Commercial		Private
	Commercial	Motor	Oar	(Oar)
Group Structure				
Number in party	28.8	29.8	21.4	17.3[1]
Number in boats	2.5	2.0	5.1	9.4
Number of people per boat	13.3	15.2	4.8	2.0
Time spent in the Canyon				
Length of trip (days)	8.6	7.3	14.4	17.3
Total number of attraction sites visited	12.9	12.1	17.0	21.3
Average length of stops at sites (hours)	2.3	1.3	6.0	3.9
Contacts with other trips				
Number of river contacts per day	3.5	3.8	2.2	2.8
Number of people seen per day (on river)	74	80.9	44.3	61
Number of boats seen per day (on river)	8.9	9.7	5.4	6.3
Minutes (per day) in sight of other parties	38.7	41.0	28.3	41.1
Number of adjustments per day for crowding	.40	.43	.23	.26

[1]This figure is inflated, since one private trip was composed of two groups which traveled as one (of 35 persons). Average private trip size is nearer to 15, and might, according to Park Service records, be as low as 12.

spend a longer time in the Canyon and visit a greater number of attraction sites. Since private trips are virtually all oar trips, it's important to know whether these differences are due to differences between motors and oars, or the commercial-private dimension. When separate means for commercial motor and oar trips on these same variables are shown (columns 2 and 3, table 6), commercial oar trips differ from commercial motor trips in the same ways that privates differ from commercial trips, but to a lesser degree. So some of the difference between commercial and private are due to the motor-oar distinction.

Private river runners were more likely to object to motor noise and show strong preference for oar travel (table 7). They also perceived more crowding--they were more likely to say they had met too many people during their trip. They were also more likely to perceive the canyon as affected by use. These differences between private and commercial trips are essentially the same differences one finds between

Table 7.--*Perceptions related to travel mode*

Variable	Correlation trip type (commercial-private)[1]	Correlation with propulsion (oar-motor)[2]	Correlation with trip type controlling for propulsion
Opinions about			
motor noise	.42*	-.61*	.04
Canyon more wilderness if motor travel banned	.37*	-.44*	.10
prefer to run river with oar trip	.45*	.63*	.05
Contact with other parties			
prefer to meet oar trips	.39*	-.53*	.04
preferred number of contacts	-.18*	.21*	-.04
Perceptions of use			
Canyon perceived as crowded	.22*	-.23*	.07
Canyon perceived as affected by use	.30*	-.35*	.08

[1]Coded 1 = commercial, 2 = private
[2]Coded 1 = oar, 2 = motor
*$p < 0.001$

otor and oar trips (column 2, table 7). nd when propulsion is controlled for--that s, the differences between private and ommercial trips within the category of ar-motor trips are examined--the dif- erences decrease in magnitude or disappear ltogether. The motor-oar distinction eems to be more critical than the private- ommercial distinction insofar as attitudes, references, and opinions are concerned.

Private passengers showed a greater illingness to pay for their encounter references, opposed more conveniences, and ndicated greater knowledge of the canyon.

In sum, an increase in the proportion f private users would have some effect on he composition of the river-running pop- lation. Specifically, the population ould be younger, include more men, and ore people with river running experience. ith respect to attitudes and perceptions inked to the trips, however, the differ- nces between commercial and private trips ere not as great as those between motor nd oar trips. Thus an increase in private sers will have effects similar to that of n increase in oar users. This is not nly because private trips are primarily ar trips and share trip features with ommercial oar trips, but because commer- ial oar passengers and private oar pas- engers are more alike in terms of atti- tudes, preferences, and opinions about travel mode, contacts, and the trip itself.

CONCLUSION

Management implications that emerge from this study are:

(1) Managing for user satisfaction implies extremely high density levels. This is probably inconsistent with the kind of experience most recreational managers are expected to provide and is certainly inconsistent with what is normally defined as wilderness recreation.

(2) User attitudes and preferences are likely to be developed *during* the recreation experience, and people tend to endorse the kind of experience they have. This is sup- ported by the fact that there were few pre- trip differences between commercial motor and oar groups, yet both tended to endorse the travel mode they experienced. The absence of expectations regarding number of contacts and people encountered for most passengers also supports this con- clusion. It is possible that user pref- erences and attitudes grow out of the kind of experience managers provide. The im- portance of the kind of experience pro- vided (particularly for first time users) is underscored.

RIVER PRESERVATION AND RECREATION PROGRAMS

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ABSTRACT.--The circumstances that led to the passing of the Wild and Scenic Rivers Act in 1968 are reviewed. Also, the legislation that has been considered and passed since the Act was passed with respect to adding rivers to the National Wild and Scenic Rivers System are discussed.

Of the more than 3 million miles of rivers and tributaries in the United States pouring their waters down to the sea, many have been harnessed for flood control, navigation, hydroelectric power, municipal and industrial water supply, and irrigation. Cities, factories, and homes have been built on their flood plains. Their banks have been dumping grounds for waste materials and their water the recipient of our industrial and municipal wastes. In many ways we have destroyed the beauty and purity of these streams. Our affluent society has become an effluent society. It has destroyed the water we drink, as well as the values of fish and wildlife and scenic and recreation resources.

In 1961, the Senate Select Committee on National Water Resources recommended:

> "That certain streams be preserved in their free-flowing condition because their natural scenic, scientific, esthetic and recreational values outweigh their values for water development and control purposes now and in the future".

This recommendation was reinforced by the Outdoor Recreation Resources Review Commission when it concluded in its final report in January 1962 that: "Certain rivers should be preserved in their free-flowing condition and natural setting". Because of the unique scenic and recreational values that certain rivers provide, the Commission endorsed efforts to preserve them in their natural condition. To accomplish this objective, it recommended that studies be made to identify rivers or river segments having these values.

In 1962, the Secretaries of the Interior and Agriculture directed a joint effort by the two departments to set up a national system of free-flowing rivers. A wild rivers study committee was selected to formulate a procedure for setting up the system. All of the States were contacted and with their assistance a list was compiled of 650 rivers worthy of consideration. Field study teams were organized with representatives of Federal agencies and the States. The teams culled the list down to 67 rivers. A reconnaissance was then made of these 67 to determine their suitability for possible Federal designation. On the basis of this reconnaissance, a more detailed study was conducted on 22 rivers that appeared to deserve some type of protection or preservation in a free-flowing condition. Legislation to accomplish this objective was drafted and submitted to the Congress.

WILD AND SCENIC RIVERS ACT

In October 1968, after 6 years of discussion and debate, the Wild and Scenic Rivers Act became law. The Act established the principle that certain selected rivers and their immediate environments possess outstanding scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values and should be preserved in a free-flowing condition for the benefit and enjoyment of present and future generations.

The clear intent of Congress in the Act was to establish a system of areas distinct

:om the traditional concept of a National ırk. Rather than acquiring a massive land :ea, the Federal agency managing a component f the National System is to acquire only a ırrow strip of land sufficient to protect ıe river environment. The acquisition of ınd is limited to an average of no more than)0 acres per river mile, and the power of ninent domain is suspended when fee title) 50 percent of the authorized area is in ıblic ownership. Additionally, scenic ısements may be acquired in sufficient nount to make the total acquisition not ɔre than an average of 320 acres per mile. This is equivalent to a river corridor veraging 1/2 mile wide.) The effect is to ɛrmit continued agricultural and resi- ɛntial use near rivers in the system, ıt to preclude heavy development that ɔuld impair the character of the river ıvolved.

The Wild and Scenic Rivers Act stablished the National Wild and Scenic ivers System, initially composed of eight ivers, and identified 27 other rivers to be :udied for possible inclusion in the ational System.

The Act encourages State rivers to be ıcluded into the system by providing that ɔon request of the Governor of a State, ivers that have been designated by the State ɛgislature as wild, scenic, or recreational iver areas and that meet the criteria set ɔrth by the Congress and supplemental :iteria developed by the Secretary of the ıterior, may be protected as part of the ational System. In addition, the Act ıthorizes the Secretary to provide echnical assistance, advice, and encourage- ɛnt to the States, political subdivisions, ıd private organizations in their efforts) establish State and local wild, scenic, ıd recreational river areas.

RIVER STUDIES AND REPORTS

River studies are conducted under the ɛadership of the Department of the Interior : the Department of Agriculture with repre- ɛntatives of concerned States, their political ıbdivisions, and concerned Federal agencies. ıe studies form the basis of reports to the :esident and the Congress. Each report ɔntains information and makes recommendations ɔout the river's eligibility for inclusion ı the National System, and indicates how ses of the land and water would be enhanced, foreclosed, or curtailed if the river and its adjacent land were added to the system.

PRESENT SYSTEM

Since October 1968, seven rivers have been added to the National System under Federal administration and 31 additional rivers have been designated for study as potential components of the National System.

As of November 1976, there were 19 rivers or river segments, totalling 1,655 miles, in the National Wild and Scenic Rivers System. Eleven of them have been added since passage of the Act (fig. 1). River mileages, by classification, are approximately: Wild, 689; Scenic, 463; and Recreational, 503 (table 1). Fifteen of the rivers in the National System are administered by Federal agencies (National Park Service, Forest Service, Bureau of Land Management, and the Fish and Wildlife Service); four are under the administration of States (Maine, Ohio (2), and North Carolina); and on two rivers the administrative responsibilities are shared by Federal agencies and the States of Tennessee, Minnesota, and Wisconsin.

Twenty-four States have a river preser- vation program, backed by specific legislation, to enhance the value of their free-flowing rivers. Two other States have administrative or executive authority to begin scenic river programs or to study selected rivers for inclusion in a State system. This does not mean, however, that all these States have strong and effective river-preservation mechanisms in effect. The programs run the gamut from merely an "intent" to begin a program to a few States with established scenic river systems and effective land use control measures in force.

PROGRESS AND PROBLEMS

The studies of the wild and scenic river proposals have become more complex as a result of the need to consider the requirements of the National Environmental Policy Act of 1969 (including the preparation of environmental impact statements), various State and Federal water quality acts, the Principles and Standards for Planning for Water and Related Land Resources developed by the Water Resources Council, the efforts to solicit public participation in the planning process, and other legislation. This, together with the efforts to solicit State participation in the

Figure 1.--*National Wild and Scenic Rivers System (As Authorized by P.L. 90-542 As Amended).*

acquisition, development, and administration of all or portions of the proposal, has slowed study progress.

Irrespective of these problems, nine of the river studies have been completed and submitted to the President and the Congress. Nine additional study reports are under review by the Executive Office of the President. The 94th Congress enacted legislation on three of the river studies prior to clearance by the Executive Office and, hopefully, the remaining six will be cleared for consideration early in the next session of Congress.

In 1975 and again in 1976, the Departments of the Interior and Agriculture jointly prepared a list of 20 additional rivers that they recommend for study as potential candidates for addition to the National System. We are hopeful that the legislation will be cleared for consideration by the 95th Congress early in the 1st Session.

Although the Wild and Scenic Rivers Act established a National Wild and Scenic Rivers System, it did not define the system or describe the extent, geographic distribution, and balance of types of rivers to be included. The Bureau of Outdoor Recreation has begun to define what should comprise the minimum system and is identifying all rivers or river segments 25 miles or longer that appear to be free from development, have good water quality, and sufficient streamflow to provide for a quality recreation experience. After review and consultation with representatives of Federal and State agencies, private organizations, and the public, the list of rivers will be reduced to those best qualified to be candidates for the National System. A fairly detailed

Table.--*River mileage classifications for components of the National Wild and Scenic Rivers System, October 1976*

River and State	Administering agency	Classification: Wild	Scenic	Recreational	Total
		Miles			
Middle Fork Clearwater, Idaho	USFS[1]	54	--	131	185
Eleven Point, Missouri	USFS	--	44.4	--	44.4
Feather, California	USFS	32.9	9.7	65.4	108
Rio Grande, New Mexico	BLM	43.90	--	0.25	44.15
(Rio Grande management by Agency)	USFS	7.85	--	0.75	8.60
Rogue, Oregon	BLM	20	--	27	47
(Rogue management by Agency)	USFS	13	7.5	17	37.5
St. Croix, Minnesota and Wisconsin	NPS	--	181	19	200
Middle Fork Salmon, Idaho	USFS	103	--	1	104
Wolf, Wisconsin	NPS	--	25	--	25
Allagash Wilderness Waterway, Maine	State of Maine	95	--	--	95
Lower St. Croix, Minnesota and	NPS	--	12	15	27
Wisconsin	States of Minnesota and Wisconsin	--	--	25	25
Chattooga, North Carolina, South Carolina, and Georgia	USFS	39.8	2.5	14.6	56.9
Little Miami, Ohio	State of Ohio	--	18	48	66
Little Beaver, Ohio	State of Ohio	--	33	--	33
Snake, Idaho and Oregon	USFS	32.5	34.4	--	66.9
Rapid, Idaho	USFS	31	--	--	31
New, North Carolina	State of North Carolina	--	26.5	--	26.5
Missouri, Montana	BLM/FWS	72	28	59	159
Flathead, Montana	USFS/NPS	97.9	40.7	80.4	219
Obed, Tennessee	NPS/State of Tennessee	46.2	--	--	46.2
Total		689.05	462.7	503.4	1,655.15

[1]USFS = USDA Forest Service; BLM = Bureau of Land Management; NPS = National Park Service; FWS = Fish and Wildlife Service.

reconnaissance will be made of the rivers on this reduced list to identify their specific qualities and develop a priority ranking. Following approval by the Administration, the proposed minimum system would be transmitted to the Congress.

Although not covered under the Wild and Scenic Rivers Act, the Department has an active rivers program in Alaska. In compliance with the Alaska Native Claims Settlement Act, the Bureau of Outdoor Recreation completed detailed studies on 28 rivers in Alaska. As a result of these studies, the Secretary of the Interior has proposed adding 20 new units with a total of 2,753 miles of river to the National Wild and Scenic Rivers System. Although 16 of these rivers lie within the boundaries of other areas proposed for addition to the National Park, National Wildlife Refuge, and National Forest Systems, four rivers with a total of 705 miles of river and 800,000 acres of adjacent land would be established as separate units of the system.

In addition, under the provisions of the Naval Petroleum Reserves Production Act we will be studying the rivers in Petroleum Reserve No. 4 in Alaska to determine whether they should be considered as potential candidates for the National System.

The designation of long stretches of rivers as components of the National System could be prohibitively expensive if large tracts of land must be bought. Because of this, we are continually seeking methods of providing the necessary land use control to protect the river environment without having to acquire full fee title to the land. Thus, the proposals, which we hope to transmit to Congress soon, will include utilization of scenic easements, zoning, and other forms of land use control.

We see control of use as one of the major management problems today and one that is going to become even more critical as the demand for river recreation experiences

increases and the supply of quality resources decreases. We must have the methods that permit us to determine the carrying capacity of a stream that is consistent with the preservation of the resource as it has been classified. Once established, the management plan for the river must control use at, or below, that capacity so we can assure preservation of the resource and a quality recreation expereince for the user.

Lack of acceptance on the part of some segments of the public is another problem we must resolve. Part of the problem is a matter of definition. The Wild and Scenic Rivers Act establishes three classes of rivers--wild, scenic, and recreational. The differences between the various classifications are the degree to which there is evidence of man's presence in the river environment. Wild rivers are essentially primitive with little or no evidence of man's presence and are accessible only by trail. Scenic rivers are largely primitive and undeveloped but are accessible in some places by road. Recreational rivers are readily accessible by road or railroad and have some development along their shorelines. However, many people equate "wild river" with a white water experience and find it difficult to understand how their remote, slow-moving stream can be considered wild. Scenic designation seems to be fairly understandable. However, recreational classification frequently makes people think the area will be overdeveloped for recreation activities. These and other misconceptions regarding the program must be corrected at every opportunity if we are to receive widespread public support and understanding.

A great deal has been accomplished since October 1968, and we are taking significant actions to maintain the momentum we have generated over the past 8 years. In the short term, we are hopeful that the Executive Office of the President will clear for release the study reports completed by the Departments of the Interior and Agriculture, and the legislative proposal to designate 20 additional rivers for study. Further, we anticipate that the Congress will begin considering the proposals submitted under the Alaska Native Claims Settlement Act, including the proposal to add 20 rivers to the National System. We expect to complete our analysis of the Nation's remaining free-flowing rivers by early 1978. Following that, we propose to develop a Nationwide list of rivers for consideration by the Congress as potential candidates for study for possible addition to the National Wild and Scenic Rivers System.

MANAGING CORRIDORS IN MULTIPLE OWNERSHIP

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ABSTRACT.--Planning and management techniques for river corridors in multiple ownerships are described. The Lower St. Croix National Scenic Riverway between Minnesota and Wisconsin is used as an example.

The title can be taken to describe :her of two situations: first, multiple)lic ownership, i.e., local, State, and ieral lands within a river corridor and; :ond, the existence of both public and ivate lands along a river. Both of these :uations present planning and managment)blems not generally endemic to single-iership, single-management river corridors. :ause of these problems, agencies, and vernmental units must seek creative :hods for protecting rivers.

Irrespective of ownership patterns)ng any designated wild and scenic river : goals and policies are essentially the ne. The policies are generally statutory, it P.L. 90-542 or a State wild and scenic vers act. However, the methods used to iieve river protection differ considerably.

Perhaps the single most important dif-:ence between river management along rivers :dered by both public and private lands, l those not in multiple ownership, is it along multiple ownership corridors ere are fewer available management :ions. Specificially, such techniques user rationing or establishing a use ireshold" are generally not feasible)ng rivers where there is considerable ivate land and virtually unlimited access.

Further, in developing a successful)tection program for river corridors, : manager must recognize the importance the "private" partner. Cooperation of idowners, local businessmen, citizen ganizations, and others, is the key to :cess. Constant communication between iaging agencies and the public is not a cury, or "something nice to do if we have ne." It is essential.

We would like to focus on the particular problems associated with planning and management of river corridors in public and private ownerships, using the Lower St. Croix National Scenic Riverway as an example of both multi-public and private ownership corridor management.

PLANNING

When an agency sets out to prepare a plan for a river in multiple ownership, it must first make sure that the public is involved at every step of the process. In trying to prepare such a document some problems, conflicts, and differences in attitudes become immediately apparent. It is readily discovered that the ability to effectively deal with certain "pre-existing" problems is constrained by legal, fiscal, or other parameters. There might be legal constraints on controlling of water surface uses or pre-existing, incompatible land uses. Multiple ownership rivers are most often characterized by: virtually unlimited access; some incompatible, pre-existing land uses; user conflicts; multiplicity of jurisdictional authorities; and overlapping federal, state and local authorities over land and water resources. Given this situation, some would ask why even try to protect such a river? Well, these are the ones, in our opinion, that are most in need of special protection. Typically, they are closer to populated areas, yet still in a near-natural condition. As such, they can be used by a large segment of the population that will never see the "wild" rivers in the less populated areas of the United States. Often, these rivers are the types of rivers included in state wild and scenic river system or are state-administered components of the National Wild and Scenic Rivers System.

Planning of such multiple ownership river corridors means accepting certain pre-existing land and water uses as irreversible. Roads, private developments, and user conflicts are generally "givens" before management planning begins. This is why most managing agencies responsible for such rivers have established a policy of not trying to turn back the clock but rather to protect the river in its existing near-natural condition.

Along these rivers, the legal and fiscal constraints are often more limiting to management than they are to river-corridors completely in public ownership. For example, an agency can only do so much toward regulating public use of waters and must stay within the legal authorities for land use zoning of private lands. Frequently, controls which are quite desirable from a river protection standpoint would involve a "taking" of private property rights. In addition, the acquisition and relocation of incompatible developments would mean the acquisition of multimillion dollar townhouses, marinas, and other developments and simply is not a viable management alternative.

For these reasons the cooperation of the public is critical to the success of managing such river corridors. If the agencies expect the cooperation of the public in managing such rivers, the public has a right to expect to be involved in all aspects of the decision-making. We feel strongly that if the public helps write the plan, they'll help underwrite it.

Rumors, misconceptions, and misunderstandings are a way of life in such government planning. For this reason alone, opening the public planning process is quite essential to public understanding and support. Often the worst fear is the fear of the unknown. As an advertisement states: "The best surprise is no surprise". From a citizen's standpoint this is certainly a fact in river planning.

The typical ingredients of a management plan for a river corridor in multiple ownership generally includes some local zoning, fee and scenic easement acquisition, and a recreational development plan. Of course, the use of these "ingredients" varies depending on the particular river and the legislative authority. The effectiveness and application of these techniques is described in some detail in the following section.

MANAGEMENT TECHNIQUES

Zoning has generally been a poor too[l] for protecting anything, especially sceni[c] river corridors. Yet, under some State statutes and regulations, the effectivene[ss] of zoning as a tool has been significantl[y] increased. For example, the Michigan sce[nic] rivers programs provides for local zoning ordinances based on State standards. Ohi[o] promotes local land use ordinances to gui[de] compatible development. Minnesota's prog[ram] provides not only for the mandatory adopt[ion] of comprehensive local zoning ordinances, based on State standards, but further prov[ides] a mechanism for the "veto" of local zoning decisions that are incompatible with prote[ct]ing a designated river and its adjacent lands. However, even the best zoning must be backed up with some type of acquisition (Minnesota Department of Natural Resource[s] 1974).

Scenic Easements

Scenic easements are being used to protect river corridors by both the Federa[l] and State governments. Although the particular terms of the easements vary, they essentially amount to purchasing the development rights on property. In additi[on], these easements generally *do not* allow public use of a property.

In theory, easements seem ideally sui[ted] for river preservation. They can protect scenic river corridors, vistas, and views without having to purchase them outright. Along most rivers, public use of the entir[e] corridor is not feasible nor even desirabl[e]. Scenic easements offer several possible advantages to both the managing agency and private landowners alike. For example, sce[nic] easements generally cost less than fee tit[le]; the agency can thereby stretch the impact of its acquisition funds. The easements of[fer] permanent protection that zoning cannot. Land remains on the tax rolls; and they hav[e] negotiation flexibility that fee title doesn't (negotiable easement terms). From the land-owner's perspective, they often can use the[ir] property as they have in the past, yet they are paid for the easement. The landowners also retain the fee ownership of the propert[y], and tax assessments may go down as a result of the sale of a scenic easement (Allen and Polland 1974 , Ohio Conservation Foundation [n.d.]).

While the use of scenic easements for
otecting river corridors seems quite
tractive we believe it is still too early
know whether they will be a sound invest-
ent. There is not a great deal of history
successful enforcement of easement terms.
addition, the "incremental" administrative
sts of easement enforcement, over many
ears, may far outweigh the initial cost
fference between easement and fee title
rchase.

Fee Title

Along multiple ownership river corridors,
e title acquisition is used in varying
grees by managing agencies to accomplish
eir management goals. In Minnesota, fee
quisition is held to a minimum. It is
nerally used only for lands intended to
developed as public use sites and to
nsolidate existing blocks of public lands
.e., within existing parks, forest, and
fuges) (Minnesota Department of Natural
sources 1974).

Some agencies are pursuing a goal of
quiring a strip of fee title land along
e entirety of a designated river. Based
the authors' experience this is a goal
at is only feasible when the managing
encies have eminent domain authority.

AN EXAMPLE:
E LOWER ST. CROIX NATIONAL SCENIC RIVERWAY

The Lower St. Croix National Scenic verway was established by law (P.L.92-560) October 25, 1972. Within this 52-mile ach of river from the dam at Taylors lls-St. Croix Falls to the confluence with e Mississippi River, are most of the mponents of the 2 types of multiple nership river management. This river gment was the first to be added by gislation after the original eight nstant" rivers were placed in the National ld and Scenic rivers system in the organic t of 1968 (P.L.92-542). It is perhaps e most urban of all national system gments, and it was because of this charac- ristic that the 1972 act had to be a operative effort between the States of nnesota and Wisconsin (whose common border formed by the river) and the federal ministration. The 1972 act specified that e upper 27 miles would be managed by the tional Park Service and the lower 25 miles the 2 states, with the State park and fish hatchery areas lying within the Federal zone to remain under State management.

However, there are several other reasons why this river reach represents a classic case of multiple ownership river administration:

(1) At the time the 1972 act was passed, approximately 83 percent of the river front properties on the Lower St. Croix were in private ownership. Not only did this constitute the great majority of land control in the corridor, but that control was in the hands of over 1,200 different private owners.

(2) At the time of the Lower St. Croix designation, there were only 2 or 3 incorporated communities on all of the 8 "instant rivers" in the national system; however, the Lower St. Croix had 15 incorporated municipalities in the corridor. Since the Federal act--and later State acts--did not allow for acquisition of property by eminent domain within an incorporated community which had in effect a proper riverway zoning ordinance; this virtually guaranteed that there would have to be a strong Federal-State-local government management partnership if the riverway was to have a continuity of protection.

(3) While about half the length of the Lower St. Croix riverway is under Federal administration, nearly all of the intensive public recreation use areas are centered around 5 State parks, one State wildlife management area, 14 public boat/canoe launch sites, 12 county or municipal parks and beaches, and about 20 nonfederal river islands. The private operators have 5 canoe or boat liveries, 2 excursion boat operations, 8 commercial boat launch sites, and 13 marinas (plus 5 more immediately adjacent on the Mississippi River).

(4) The entire Lower St. Croix river is also under the jurisdiction of the U.S. Army Corps of Engineers and U.S. Coast Guard for navigation channel maintenance and marking. The entire federal zone is identified as "an authorized 3-foot channel" but the Corps of Engineers has not dredged the reach since 1906 near the end of the steamboat and loggin era. The lower 25-mile State zone of the riverway is part of the 9-foot navigation system on the Upper Mississippi waterway allowing for full-sized tow boats and barge tows to navigate from the Mississippi as far as Stillwater,

Minnesota. Barge tows do ply the river as far as the large Allen S. King electric generating plant on the Minnesota side, carrying approximately 1.5 million tons of coal annually (U.S. Department of Interior 1975b , 1976).

One might well ask why such a complex area should even be nominated for inclusion in the National Wild and Scenic River System? The reason is that the Lower St. Croix still possess outstanding scenic and recreational amenities; even today, most of the valley appears to the observer to be relatively unspoiled.

In a political sense, it is commonly said in the local area that the citizens designated this river themselves years before the Federal and State governments did. Indeed there was a tremendous amount of spontaneous citizen activity directed at preservation of the exceptional qualities of the valley in the early 1960's when the largest electric utility in Minnesota proposed to construct the Allen S. King plant along the Lower St. Croix. This 500-megawatt coal-fired plant was the first major industrial intrusion into the valley since the end of the logging era in 1914.

Despite the great complexities of multiple ownership management of the Lower St. Croix, there are two fundamental reasons why this program is effective. The first reason is that *public support for riverway protection and management is still quite high*. The processes of formulating management plans for the riverway have been kept wide open; thus, there has been an unprecedented opportunity for local officials and interested citizens to participate directly in the shaping of the management of the Riverway the citizens designated.

There has been some lack of continuity among local leaders over the period of involvement. One of the reasons has been that many of those who were active in the "local governmental conference" in its formative years are no longer in office. This would be expected in any similar multiple ownership river situation. In addition, one of the greatest dangers in the implementation phase of river management in a multiple ownership situation is public apathy. Once river designation is achieved and management activities begin, there is a tendency on the part of the local and private partners to sit back and "Let the other guy do it". Therefore, consistent river management requires an effort to continually inform local riverway leader and to bring them in at the "action" leve The authors are convinced that without fairly widespread and articulate public support, a river management plan in a multiple ownership river corridor will be unsuccessful.

The second reason why this program is effective is that *the managing agencies have cooperated closely in the achievement of their management goals*. The fact that the river is "interstate water" is a blessing in disguise because the two State in joint legislative action in 1965, established an interstate commission--know as the Minnesota-Wisconsin Boundary Area Commission--to be an unofficial coordinato and watchdog over river policies and issue The commission has been heavily involved i the task of "tying together the loose ends of Lower St. Croix River management.

Cooperation and coordination of manag bodies is essential. After 4 years of experience working together, the two State governments and the National Park Service easily saw the wisdom of developing a semi formal managment partnership. In August o 1973, Governors Anderson of Minnesota and Lucey of Wisconsin joined with the Regiona Director of the National Park Service in signing a cooperative agreement in which the three "partners" pledged to work togeth to protect the riverway under the umbrella of the joint master plan and the coordinat of the Minnesota-Wisconsin Boundary Area Commission.

The Lower St. Croix Management Commiss composed of top representatives of the Minn and Wisconsin Departments of Natural Resour and the Riverway management of the National Park Service, has established a working technical committee which meets monthly und the chairmanship of the executive director of the boundary commission. All matters having to do with the management of the riverway are discussed at these meetings and if necessary, brought to the management commission for discussion. This tool provides for effective communication, promotes a spirit of cooperation, makes the program operate efficiently and provides for joint ventures, (such as an upcoming river use survey which could not be accomplished independently).

FUTURE PERSPECTIVES IN RIVER RECREATION MANAGEMENT

REGIONAL RIVER RECREATION MANAGEMENT

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ABSTRACT.--Describes the evolution of the Interagency Whitewater Committee; its present functions; and its potential for the future. Emphasizes the need for considering a regional approach to river management.

INTERAGENCY WHITEWATER COMMITTEE/CONFERENCES

History and Development

In February 1973, representatives of the Bureau of Land Management, National Park Service, and USDA Forest Service held a meeting in Salt Lake City to consider common river management problems and programs. They were impressed by the commonality of their problems, and the fact that commercial river outfitters were better informed on what was going on, regionally, than they were. Consequently, they met again the following August, at Dinosaur National Monument. As a result, an Interagency Whitewater Committee (IWC) of five agency representatives was established to develop Whitewater Management Guidelines.

In November 1973, the IWC was expanded to nine members: three from each agency to insure representation from a wider geographic area. It has since functioned as a sterring committee on a year-round basis, providing continuity of communication and informational services, and planning future conferences. A representative of the U.S. Coast Guard was added to the Committee in November 1974. Representatives of the Corp of Engineers, Bureau of Reclamation, and Bureau of Outdoor Recreation attended subsequent conferences. Although the committee functions as a Federal agency committee, State and local agencies as well as private organizations have participated in conferences.

Conferences have covered such divers topics as noncommercial use, U.S. Coast Guard regulations, transfer of commercial permits, human waste disposal, food handl g, State and Federal cooperative river management programs, safety, and season-end reviews at the fall sessions.

Half of the February 1976 session wa devoted to river research programs. Managers were cautioned that researchers car not and should not attempt to provide all of the answers and write the manager's ma agement plan. However, research can provide valuable, and probably essential inp for management.

Management Guidelines

The Interagency Whitewater Managemen Guidelines "is *not* a policy statement, no does it constitute or have basis in statutory authority, but rather it is a docum which the managing agencies can use *as a guide when appropriate. Neither the IWC nor the guidelines decide local river management or operational decisions.* Such decisions are decided by the appropriate agency..."

The Guidelines cover management obje tives, capacities and limitations, allocations and allotments, commercial operatio noncommercial permits, operational require ments, research, safety, and interagency cooperation. An appendix includes lists of about 125 managing agencies, commercia outfitters, and first aid and safety supplies; use statistics; a suggested commer permit as well as noncommercial river tri

plication and permit; public health andards; a review of current allotment thods and permit requirements for individual rivers; and information on navigable vers.

ate/Federal/Canadian Cooperative Efforts

Both State and federal officials attend ssions such as the Interagency Whitewater nagement Conferences and the Western ates Boating Administrators Association SBAA) conferences. Specific offices at th levels of government have pioneered in ver management and much information is ared among State and federal land agencies. nagement responsibilities are also shared some rivers, demanding additional coopation if the public is to be properly rved.

Representatives of Canadian agencies e now on the IWC mailing list and are in mmunication with U.S. agencies in response recent, noticeable increases in riverinning on Canadian rivers. Regional etings such as sponsored by the IWC and BAA should continue, both to benefit the wly appointed river manager and to prode additional insight into river managent for seasoned managers. The casual e-to-one discussions in an informal atsphere can be as valuable as the formal esentations. Such meetings should involve cal, State, federal and Canadian represen-tives, along with researchers and river ers.

FUTURE PROGRAMS

The following discussion anticipates ne ways in which river managers may meet ture challenges. The crystal ball utized is the property of the authors and es not necessarily reflect the opinions their agencies or other river managers.

IWC - The Future

The IWC has served managers as an inrmal forum in which to exchange ideas l experiences. Its Guidelines have proded needed consistency to management proaches. Should it continue in this nited capacity, be disbanded, or expand s role? The opportunities afforded by tending IWC activities have convinced that only through such cooperative forts are regional problems of river manement to receive adequate, effective tention. As the use of one river becomes more restricted and the numbers of users increase, use pressures seem to shift to other rivers and to other regions. Existing problems on one river become the future problems on other "newly discovered" rivers. Hopefully, the management errors need not be repeated, and where appropriate, successful programs can be considered.

It is doubtful that the Committee can continue to exist very long in its present form. Higher levels of management in the member agencies are becoming increasingly hesitant to commit funds and manpower to such a group without a formal and recognized charter. But neither are river managers prepared to disband the IWC because of the unsolved challenges requiring their collective resources.

What roles might a formal and expanded IWC play? The spectrum could vary broadly from that of developing passive guidelines to providing management direction. It could serve as an information forum or to formulate policy. Its proper role probably lies somewhere between these extremes. If river managers are not able to cope with their problems through interagency cooperation, political decisions will certainly fill the leadership void.

East and West

The IWC presently includes only federal river managers from the western States and deals specifically with problems in these States. White-water boating, however, is growing throughout the United States. Therefore, should the scope of IWC be expanded to encompass eastern rivers under federal jurisdiction? It is doubtful that one national organization would serve managers as well as two regional ones, east and west. Because of differences in user populations, land ownership patterns, river character, climate and population distribution, many problems managers face are regional.

Eastern white-water river managers might find an eastern interagency committee as productive as the western one has been. If an eastern counterpart to IWC is organized, joint conferences would provide a stage for national coordination of information.

Policy and Planning

Certainly no agency can formulate

policy in a vacuum. It must consider input from both management and the public. The IWC can provide a sounding board for river management policy proposals from a regional viewpoint. The Committee could also enter such areas as management plan review if requested by agencies. Because of the mandates and policy differences between the three land agencies, the Committee should not be involved in decisionmaking on other than an advisory basis.

Public and State Involvement

The IWC should retain its identity as a federal organization of federal employees. The IWC cannot include interested people from the public sector or State authorities (as has been suggested by some State officials) without becoming an advisory committee within the scope of the Federal Advisory Committee Act of October 6, 1972 (P.L. 92-463). Management conferences sponsored by State and Federal organizations will continue to provide the public, State and local officials an opportunity to voice their opinions and communicate with individual federal river managers.

IWC Makeup and Function

The IWC is made up of field level river managers. Some managers fear that formal organization will mean a shift of membership to higher level agency people, thus losing close contact with day-to-day problems. This is certainly a possibility, depending on the Committee charter. However, any concern that formal organization would discourage a free exchange of ideas would seem unfounded. Managers will still be in contact at conferences during and after organized programs.

Services

A formal IWC could provide a vehicle for regional services that cross agency lines, such as a central reservation office, public information office, or management information clearinghouse. It serves the latter function now.

Role of Coast Guard

The U.S. Coast Guard is responsible for safety on all navigable waters of the United States. Until recently it has not actively pursued its responsibility on white-water rivers. This has changed, however, in response to the increase in white-water boating and the number of accidents associated with it. The Coast Guard is now developing rules for commercial passenger craft: construction standards, safety equipment, and boatman qualification. It will soon be enforcing them on rivers in its jurisdiction. The Coast Guard will likely become more active in private white-water boating also.

What does this mean to managers? It may be necessary to adjust permit requirements. Regulations and rules will have to be coordinated to avoid confusion and contradictions. Boat patrols and inspection may be combined and agencies may elect to adopt Coast Guard regulations so that the can do some of the enforcement work themselves.

The Coast Guard has arrived in white-water boating and will stay, possibly expanding its future role through coordination with land managing agencies. Although its presence is painful to some boaters, especially in the commercial sector, improved safety will probably result. Most agencies have recognized the need for better safety equipment and inspection; few have dared assume this responsibility. The Coast Guard has no such inhibitions.

Central Information/Reservation Office

The user finds himself submerged in a wave of State and Federal agencies at every bend in his quest for white-water recreation. A trip organizer's first problem is finding where and from whom he can obtain information on a given section of river. Is a permit necessary? Are there other special requirements? Who issues permits? When are applications due? The managers also have their problems of reaching members of the public who have a river running interest with information about available dates, areas, special restrictions, etc.

The IWC Guidelines introduced some structure into an otherwise chaotic situation by answering the questions of where a from whom information can be obtained. If the river user or manager is fortunate enough to encounter an agency person acquainted with the Committee he can probabl get the information he needs. Otherwise he will likely be shuttled from office to office until he reaches someone who can

lp him or gives up in disgust.

The private sector provides some urces of information. A few excellent oks are available on river touring. fortunately, management requirements have anged so fast that material in the books y be out of date before they are pub- shed. A number of organizations, such the American White-water Affiliation and erican Canoe Association, publish riodicals and newsletters.

As of 1976 permits are required for l commercial outfitters on more than 50 ver segments listed in the IWC Guidelines. ncommercial permits for those who run vers on their own without the servies of guide, outfitter, or professional boatman e required on at least 18 of these rivers. urteen of these have some kind of use mitation rule pertaining to the number permits to be issued during a single ason and/or numbers of persons permitted each float boating party. The greatest strictions are on the most popular river ctions.

Typically, permits are handled by a cal agency. In most cases, the various encies or unit officers with jurisdiction ong a particular river section have reed that one office will handle permits d reservations. No similar coordination s been developed between managers of fferent rivers on a regional basis.

The information dilemma might be re- lved by a central information center, tional or regional. It could be federally privately sponsored. The Center would t necessarily be involved in issuing rmits or making reservations, but could ovide information supplied by each par- cipating agency concerning their ailability.

The permit and reservation problem is ch more complex. The present system, ere local agency offices make reservations d issue permits, offers flexibility to al with each individual situation. How- er, this flexibility and the correspon- nce it generates is very expensive to e agencies and requires a great volume mail. Few local offices can take advan- ge of such tools as computer programs r "no-repeater" rules that require indi- duals to wait one or more years between ips on the same rivers. Many floaters sure themselves a trip by applying on several rivers for the same dates. This practice and the high rate of "no-shows" it generates can only be avoided if reser- vation systems are coordinated between rivers.

A central office, national or regional, could utilize computer systems now being developed to manage no-repeater rules and coordinate permit requests on several rivers. This office could double as an information/reservation clearing house. Conceivably, if reservations were coor- dinated between rivers, the number of "no- shows" could be reduced and capacity more effectively allocated. Permits could still be issued by local offices. They could also make short-term substitutions to back up cancellations.

White-Water River Planning-- a System Approach

We now do our planning on a river-by- river basis. Alternatives are usually selected without consideration of oppor- tunities afforded by other rivers; the planning process is often locally oriented. If the manager, however, decides to broaden his approach he will be frustrated since no means is readily available to weigh alternatives on a national or even re- gional basis.

It is doubtful that our present river- by-river approach can effectively cope with an increasing demand for a decreasing re- source. Should we evaluate viable manage- ment alternatives for a specific river without considering management on other rivers? We have opportunities to offer a range of experiences if the river system is considered as a whole. For example, some rivers may key on low density use, emphasizing solitude; others may allow high density use, keying on the white-water experience. Some may exclude motors; others welcome them.

Before considering a group of rivers in a region as a river system we have to answer some basic questions. What are people's needs and desires? What do they value most, a white-water experience even though it may be in a crowd, or a chance, however slight, to combine white water and solitude? What is the optimum mix? Researchers, managers, and public involve- ment should be able to provide some answers.

Another key to developing a white-

water river system is to find out what we now offer the boater. One approach would be to build a matrix of opportunities offered on managed rivers. This would provide a basis for evaluation of altertives for new plans and revisions of existing plans. It could be developed by researchers, managers, or both.

Who should spearhead such an effort? The IWC might do the job. Such an agency as the Bureau of Outdoor Recreation could assume the leadership role. Management agencies have discarded any vestiges of provincialism on sections of river with multiple jurisdictions. Can a similar effort succeed on a regional basis with several rivers?

SUMMARY

We see continued growth in demand for river running opportunities. River managers must seek out that optimum level of use which will allow as many persons as possible to float a river, without destroying the very values for which the area was established and is being managed. Such values can vary from area to area. What-ever they might be, they should not be compromised.

As the prospect for use becomes mor restrictive, management must seek out ideas, concerns, recommendations, etc., from the public and fellow managers. Co sideration should be given to regional information centers; to improved, more efficient management efforts so as to afford more equitable opportunities for individual float experiences; a careful look at classifying rivers by the desire level of experience; closer working relationships between local, State, Federa and Canadian agencies; continued input from the public, using improved methods; and a recognition that river management must be considered in a regional context A popular recreational activity involvin limited resources such as river-running, will result in sensitive, difficult management and use problems. We believe tha cooperative action and the integration o thoughts from many management and use sectors are essential to the resolving of these problems and the proper management of river resources.

INFORMATION NEEDS FOR RIVER RECREATION PLANNING AND MANAGEMENT

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ABSTRACT.--Information inputs to making decisions about recreational use of rivers are described. Major recreational decisions and possible inputs to them are identified. A future scenario for recreational use of rivers is given and the needed research on information inputs is identified within the context of the scenario.

So much planning and management infor-ation is being generated by river researchers nd managers that to discuss information needs eems redundant. However, there appears to be lack of focus and organization to present fforts and in that context the discussion ight be productive. River recreation re-earch seems to be going the way of most other ecreation research--ignore all we have learned bout recreation, start from scratch, and pid-le for 5 years (or more) before we define the roblem.

My own view of the future suggests that e cannot afford less than a focused, coor-inated research effort right now. We need o determine the nature of the phenomenon and hen seek the information that will allow us o manage it. In this regard, there is a remendous cooperative role to be played by iver managers and researchers. There is the pportunity to learn from past recreation esearch and to proceed with rivers research ore effectively and efficiently.

Simply put, my view of the future which alls for urgency looks like this. Within he next 10 years, I see at least a doubling f demand for river recreation. This will aise issues of user conflict, user displace-ent, and resource damage--possibly beyond cceptable limits. Within this expanded roup of enthusiasts, there will be more ovices using new equipment that they do not now how to use. The result will be increased azards and a greater public safety management rogram for river administrators. I see con-inued demand for special designations for ivers. Some of this will be for formal sta-us within the Wild and Scenic Rivers System (Act PL 90-542). Some will be for administrative designation as special use areas. This movement will mean more public involvement and thus need for more information about rivers and their uses. It will also mean that regional systems of rivers will need to be designated and studied so that rivers can be allocated to uses in an efficient manner; efficient because the resource is presently scarce and will become more so. One of the things to avoid is the polarization of supply into wild, primitive rivers and into high use, developed rivers. A regionally specific, systematic approach to allocation may be helpful in avoiding this problem.

Finally, my view suggests that there will be continued pressure to turn many rivers into lakes. Dams will be desired for energy production, flood control, irrigation and domestic water storage, and flat-water recreation opportunities. Planners especially will be required to respond to these demands by justifying why river recreation is important. If they are unsuccessful, we will lose our ability to meet river recreation demands and the doubling of demand will completely overwhelm the remaining resource.

What kinds of information will enable river managers to deal with the challenges posed by my scenario? The following sections describe the kinds of information which may be useful and give examples of their relevance.

INFORMATION NEEDS

Recreation management decisions might be approached several ways. One way is based

on carrying capacity. It fits the purpose here because carrying capacity is an integrating concept and because it is familiar to many river managers who have specified river capacity to regulate use.

The decision model into which carrying capacity fits has been presented elsewhere (Brown *et al.* 1976, Roggenbuck 1975) and is only briefly reviewed here. Three basic decision points are shown (in boxes) (fig. 1, Brown *et al.* 1976): (1) selecting management objectives; (2) selecting management tools and practices to achieve objectives; (3) selecting modifications to make in the management system, if needed. General information input to each of these decisions is shown; at each decision point, only new inputs to the process are shown; data are assumed to be carried from one decision point to the next. Activities, like implementation, that occur between the decision points are also shown. The performance of each of these actions often produces information useful for making subsequent decisions. Therefore, the output of each action can be considered as an information input comparable to those inputs specifically identified. For instance, the actual calculation of carrying capacity produces a number (or range of numbers) which is a standard indicating the maximum amount of use to be achieved. This number becomes one of the many inputs to selecting management tools--one that may limit the range of alternatives considered.

While both the decisions and the intervening activities produce outputs which become inputs to the next decision or activity, our focus here is on the explicit inputs shown in figure 1; i.e., those inputs to decisions which are inputs to that process and are related to the basic decisions of the process. A somewhat more detailed listing of the relevant information inputs to selecting management objectives, calculating carrying capacity, and selecting management tools is given in the following tabulation:

SELECTING MANAGEMENT OBJECTIVES

- User Preferences
  - Activities
  - Resource Attributes
  - Social Attributes
  - Managerial Attributes
  - Desired Consequences
- Resource Capabilities
  - Functional Capability
  - Assimilative Capacity
  - Resiliency

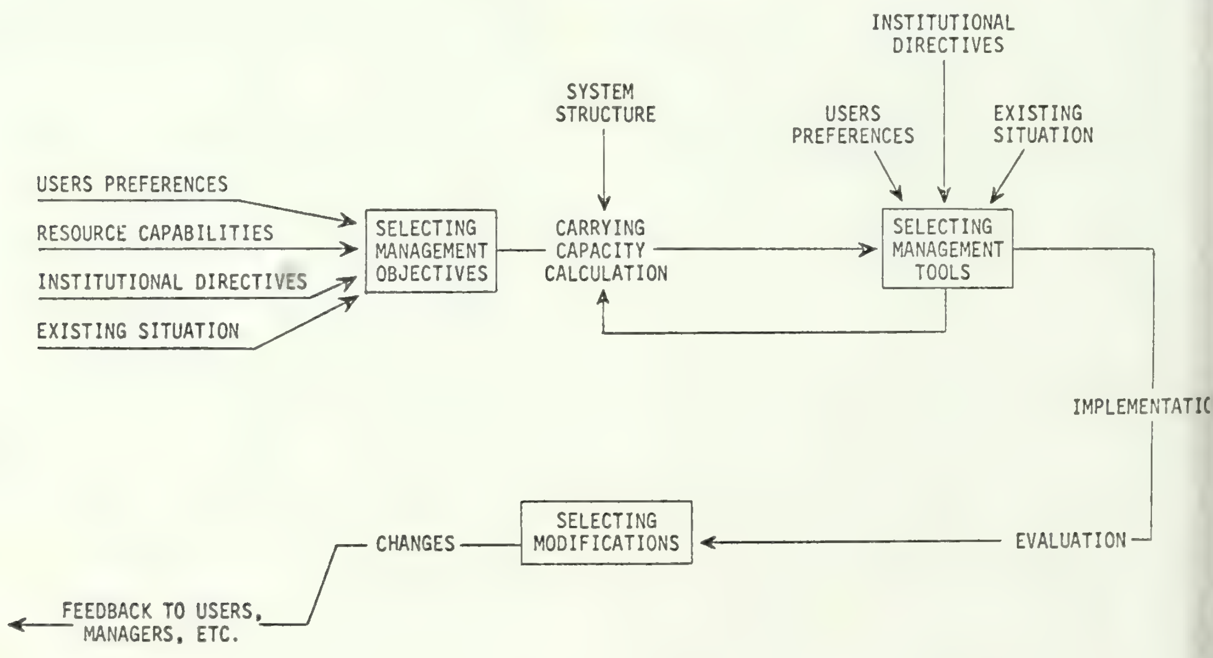

Figure 1.--*Decision points, with their inputs and outputs, for recreational management of rivers.*

Institutional Factors
  Laws
  Administrative Policy
  Budget and Personnel

Current Situation
  User Characteristics
  Resource Condition
  Management Practices

FINING THE MANAGEMENT AREA STRUCTURE

Facilities

Physiographic Elements

LECTING MANAGEMENT TOOLS

User Perception of Management Actions and Behavior

Institutional Directives

Existing Situation

SELECTING MANAGEMENT OBJECTIVES

The kind and amount of information ac-ally used by managers in selecting manage-nt objectives may be very limited, or it be extensive. Specifying a set of in-rmation needs will not necessarily change e kind, or amount of, external information ed, but it does indicate some of the kinds information useful in the "decision lculus."

User Preferences

What users prefer for river recreation, vironments, and experiences gives clues to e demands users have for river recreation d the forms it should take. Such informa-on may indicate to managers the level of pport existing for various recreational portunities, the range of opportunities sired, and the nature of the opportunities at people seek. Preferences for several nds of information, including those for tivities, natural resource elements, so-al and managerial situations, and conse-ences of recreational engagement, may be nsidered.

tivities

User preferences for activities give a neral indication of the things users like to do in an environment. It has been common to identify recreation as activities and to enumerate the activities in which people engage. To prepare management objectives, it might be useful to know what activities users would like to have offered. It may be that users are thinking of different sets of activities than managers, and information about such differences could be useful in selecting a set of activities to be included in specific management objectives. For instance, if users think of both rafting and hiking (at portages or around camp) as important components of a river excursion, the manager may want to consider both when developing management objectives because elements of the physical, social, and managerial environment may be different for each activity.

Resource Attributes

One category of things that the manager may manipulate is attributes of the resource environment. Users also exhibit preferences for different attributes which may facilitate their having satisfying experiences. If managers know what resource attributes are preferred by users, they will know what resource factors are perceived by users as being important to satisfaction and may then identify some conditions of the resource attributes to include in management objectives.

If users indicate that maintenance of a relatively natural environment along a river's edge is important to their satisfaction, the manager may then write an objective which emphasizes the riverside environment and what levels of disturbance are acceptable. Likewise, if users indicate that an invasion of trash fish lowers the quality of their river fishing experience, the manager may prepare an objective which specifies at what point the amount of trash fish is undesirable. These and many other resource factors have been dealt with by managers over the years. From the perspective of selecting management objectives, it might be useful to determine which of these factors are perceived by users as being important.

Social Attributes

The social attributes of the recreational situation may also influence whether or not users have satisfying experiences. Such items as the frequency and kinds of direct contacts between users and such indirect contacts as worn away vegetation and litter are important. Status-giving proper-

ties of recreational settings and experience may also be considered in this category.

Probably the most common expression of social characteristics in a management objective will be articulation of the kind, location, and amount of contacts acceptable for a quality experience. For river management, different kinds of contacts occur at the launching site, on the river, at campsites, and at takeout points. Also, the size and behavior of contacted groups may be of concern. In writing objectives, a manager might input preferences for different amounts of contact to his "decision calculus" and arrive at standards indicating either a desirable or acceptable number of contacts for a specific kind of recreation. Another condition for which users might have preference is the social status accorded certain areas and activities. Managers may be able to manipulate this status component by labeling or designating certain areas (e.g., Wild Rivers), or by advertising special opportunities or challenges (e.g., ratings of rapids). Preferences for these designations may be used by managers in writing management objectives which are designed for recreation opportunities that produce status outcomes.

Managerial Attributes

One other environmental attribute set, those of the managerial situation, may also influence the production of satisfying experiences. Management philosophy and approach, designation of area types, and the level and type of management activities (in terms of personnel and facilities) are all characteristics for which users might have preferences. For instance, in selecting management objectives it might be valuable to know how users feel about both regulatory and manipulative types of management. If users are opposed to regulation, the set of management objectives for consideration may be constrained. Alternatively, if users are indifferent to either type of management or are willing to accept either, there may be several options which the manager will want to consider.

Desired Consequences

Engagement in activities produces a set of consequences. Often these consequences are identifiable kinds of satisfactions and benefits; sometimes dissatisfaction results from the experience. Different users appe to seek different kinds of satisfaction an these different preferences can be identif

In writing management objectives, the may be instances when it is desirable to h information about user preferences for con sequences of the experience. If users are seeking opportunities to affiliate with others, if they are seeking achievement an skill development, if they are seeking escape from everyday environments, knowledge of such desires could be useful in selecting management objectives related to user desires. While the manager actually manipulates resource, social, and managerial factors to produce opportunities to provid these kinds of satisfaction, knowledge of desired consequences may provide a rationale for selecting specific standards to be included in management objectives and subsequent management actions. For example, if the river manager knows that users desire experiences which enable them to escape both their usual environment and many other people, he might consider management objectives which include standards dealing with length of trip, size of party, number and location of contacts between parties, and type of equipment used. These and several other variables will likely influence whether or not users have a satisfyin experience.

Resource Capabilities

The capabilities of the resource base to support different recreational activiti and to enable production of quality experiences can be integrated into decisions abo management objectives. This information m indicate which activities are physically p sible, some of the resource constraints on production of recreation opportunities, an the levels at which change in the resource may become unacceptable. Three categories of information which may be considered are functional capability, assimilative capacity, and resiliency.

Functional Capability

The simple notion that a resource bas provides an intrinsic opportunity for a recreational activity describes what is meant by functional capability: the resour is capable of supporting functional use. often say that if there is a river present there might be river recreation opportunities; if a river is not present, there is

portunity for river recreation. This no-
on does not rule out the possibility that nagement might alter the landscape to provide river recreation opportunities where ey once did not exist. What it does in-
cate is that some opportunities exist thout alteration or with enhancement only.

siliency

An idea associated with acceptable re-
urce change, and thus acceptable levels of e, is the ability of the resource to bounce ck after being stressed. Included in re-
iency is not only the bouncing back of isting objects, but also regenerative ility. Specific standards may be written to management objectives regarding resil-
ncy, particularly for soils and vegetation, t also for other resource factors.

In considering changes in vegetation, sual deterioration may be acceptable if the ility of the vegetation to recover in a ecified time is maintained; if the vegeta-
on cannot recover, the change is deemed turally irreversible. The management ac-
vity of site rotation is based on this ea. For river recreation management, the nager might consider items like vegetation, sh, wildlife, and riverside soil conditions fitting into this category. The ability predict at what level or point (threshold) nditions become irreversible is not well veloped, but in cases where the outcome of fferent use and deterioration levels is own, the manager may gain valuable infor-
tion for selecting management objectives.

vs

The laws that guide management of land d water areas may have a large influence the kinds of management objectives lected. Laws often set the boundaries thin which decisions must be made and dicate the amount and type of recreational e that is acceptable. For river manage-
nt a relevant piece of legislation might the Wild and Scenic Rivers Act 90-542). This legislation sets the tone r recreational use of wild, scenic, and creational rivers managed by Federal d State agencies. It provides general idelines for condition of the adjacent oreline environment, water quality, river poundment, recreational and other cility development, and river access der each of the river classifications.

Another kind of legislation important to river management is Federal and State water quality statutes. These statutes often either specify acceptable water quality standards, or provide a mechanism to establish standards which are subsequently promulgated. Standards like these might be used directly in the writing of management objectives.

Administrative Policy

Like laws, administratively established policy may guide the selection of management objectives. Administrative policy plays the same role as law, though it is often more specific by focusing on one agency's management style or on a particular area. For instance, an agency like the Bureau of Land Management may eventually articulate a Bureau-wide interpretation of the Wild and Scenic Rivers Act and put forth specific management guidelines for each class of rivers. This would encourage consistent management throughout the Bureau while at the same time constraining the range of options for management objectives and practices which any one BLM river manager may consider.

Institutional Factors

Institutional factors often act to direct the kind of management objectives written for any specific area. Statutes, administrative policy, and budget and personnel situations often direct and constrain the choice of objectives. Such information may include things like the range of opportunities for experiences which are possible, the management philosophy which is appropriate, and the degree to which management activities can be effective in meeting certain objectives.

Budget and Personnel

Information about budget and personnel may constrain the kinds of management objectives selected. These factors are often viewed as limiting the effectiveness of management, and information about them may lead to selection of realistic management objectives. For example, if personnel are unavailable to regulate river use by administering a permit or fee system and checking compliance with the system, objectives which require that intensity of management may not be selected. Likewise, objectives which require facility development for their attain-

ment may be rejected if budgets are expected to be very low or to not contain construction money.

Current Situation

Information about the current situation identifies the state of the management system. Also, the current situation may be quite constraining on future management actions because some options may have been lost through present and past management, and because some present behaviors (both user and managerial) may be quite difficult to change. For these reasons, the set of realistic future options that the manager has to consider may be limited.

User Characteristics

Changes in type or amount of use suggested by certain management objectives, if realized, may have an effect on user activities, distribution, group composition, and several other factors. Knowledge of who will be affected by changes is valuable. Also, knowledge about behaviors to be changed and an estimate of how easily the changes can be effected may be important in selecting management objectives.

One example where current user data may be valuable is a river where there are long-standing traditional uses. Present users will probably consider the traditional use as normal and a right. Efforts to modify that use would likely be fraught with public relations problems, and benefits accruing from the change may be far less than the costs. In a case of this nature, the manager may rule out consideration of some objectives.

Resource Condition

Present resource conditions may influence the writing of standards contained within management objectives. If resources have been used up, and reclamation would be difficult, management options would be limited to no use or development alternatives. On the other hand, if the resources are in near natural conditions, the manager may consider preservation alternatives as well as many other options. In writing standards for objectives, the manager may look at things like vegetation condition. Then he may write a biologically oriented objective which indicates that an acceptable change in vegetation is removal of not more than x percent of the present amount of vegetation.

Management Practices

Management practices often become we accepted by user publics and eventually a articulated as the way things should be d they become normative. Many possible man ment objectives will require changes in m agement practices which are difficult to implement because of the normative charac of present management. Realization of th may influence the manager's selection of agement objectives. Those objectives whi require a change to more visible and poss more coercive management may be rejected b cause of expected problems due to changin management. Likewise, objectives which r quire changing access to areas (providing access is viewed as a management practice may be shunned because of expected disrup tion of user behavior. In both of these cases, knowledge of the existing situatic and expectations of disruption caused by different management situations may influ ence the selection of management objectiv

DEFINING THE MANAGEMENT AREA STRUCTURE

In order to calculate recreational ca rying capacity consistent with the manage ment objectives for an area, it is necess to have information on the physical featu of the area which determine its physical structure. The features considered may b both man-made facilities and physiographi elements.

Facilities

Facilities such as trails and campsi are important elements of the structure o an area. They tend to channel users to s cific locations and to regulate rates of travel. They are also elements which can modified by management to increase or dec the total physical capacity of an area, given user behavior patterns. For instan in the case of rivers, the number of avai able sites for camping and the number and difficulty of portages may determine outs limits on carrying capacity at any given

Physiographic Elements

Terrain and distribution of vegetati are important factors of an area's struct For example, the steepness and ruggedness terrain and the river gradient affect rat of travel, the number of available campsi and the number of portages required. Sim

, vegetation patterns influence the t of screening afforded campsites, thus ting the number of sites which can be under some objectives (e.g., solitude), hey influence rates of travel at por- and for other terrestrial activities. er important element along rivers may e incidence and size of tributary streams may act both as barriers to travel and eators of major features (e.g., major ng holes, campsites, etc.).

SELECTING MANAGEMENT TOOLS

Several kinds of information may be use- n selecting management tools for a cho- bjective. Some of the information can rried forward from the activities of ting management objectives and defining tructure of the management area. Some information might be derived specific- for the purpose of deciding from among ray of management tools. Such informa- might be grouped into three classes: perception of management actions and behavior, institutional directives, and ing situation (fig. 1).

ption of Management Actions and Behavior

Often users have feelings about both the al philosophy of management (e.g., coer- or light-handed) and specific management . Knowing how users feel about these s may indicate which tools will be re- d favorably or unfavorably by users, hus be effective in achieving management tives. In river management, for instance, anager may have the option of limiting umber of permits available or adjusting fees to regulate river use. Which option st may depend upon many factors, one of is whether the user perceives the tool ably or unfavorably.

Some management tools have effects on behavior. Knowledge of the effective- of different tools in changing user be- r would aid decisions about which man- nt tools to use. For example, if it nsidered necessary to distribute river differently than at present, both con- ing the starting time of users and pro- g them with information about attrac- along the river are potential tools. ciding between the two a relevant ques- might be, how effective is each in mod- g user distribution along the river? swer to this question would help the manager select the tool to use, if the two tools are differentially effective.

Institutional Directives

Institutional directives may play a role in the selection of management tools. If certain management approaches are favored, or required, by an agency, then they will probably be selected by managers. Likewise, if certain techniques are discouraged or barred from use, they will be eliminated early in the decision process. In river management, permits for float trip outfitters are a management tool required by some agencies. For other agencies, permits are discouraged as management tools. Whichever the case, selection of permits as a viable management tool will likely be affected by the agency posture toward permits. Other kinds of management tools may be similarly affected.

Existing Situation

As with selecting management objectives, the selection of management tools may be influenced by existing management. Both the effectiveness of tools and the current patterns of management are important. If presently used management tools are working, and management objectives have not changed, the decision of which tools to use will probably be simple; no change is needed. If, however, present objectives have changed, then the manager may search for a new set of tools. In doing so, it is possible that he will compare new tools against those he is already using.

The patterns of management that develop in an organization may also influence the choice of management tools to use. Certain tools may lead to a particular administrative routine. For instance, if river running permits are not presently being used, their introduction would lead to changed behavior of management personnel. Some employees would need to be assigned to issuing permits, some would need to keep records about the permits, and some would need to monitor compliance with the permit system. In effect, different patterns of management would develop within the organization. In considering which tools to select to achieve management objectives, information about the effect of tools on patterns of management may indicate whether or not implementation of a tool will be disruptive or beneficial to the functioning of the organization.

SELECTING MODIFICATIONS IN THE MANAGEMENT SYSTEM

The information which might be used in deciding how to change the management system is the same as that for selecting management objectives and tools. Modification of the management system becomes necessary when either the tools are not working or the management objectives are not relevant, or both. To decide on what changes to make, the kinds of information inputs previously discussed are relevant and need no further explanation.

NEEDS FOR PLANNING AND FUTURE MANAGEMENT

While several different information items have been discussed above, which ones will really be needed in the future? What information is needed to effectively respond to the future that we visualize? Some of the information needed can be simply obtained (from statutes, manuals, reports, etc.), while other information needs to be generated through research. It is these research needs which are addressed below.

As stated previously, within the next 10 years, there will be a doubling of demand for river recreation. There will be more novices using new equipment which they do not know how to use. There will be continued demand for special designations for rivers. There will be continued pressure to turn many rivers into lakes. This view of the future is one of increased demand for recreational use of rivers and one of continuing special interest demands for river allocation and possibly modification.

In responding to this future, there are several research needs to produce information for today's planning and tomorrow's management. First is the need to *identify the kinds of user demands* which might exist for river recreation. Information on what consequences are desired from recreational experiences and on what resource, social, and managerial attributes are perceived to help produce satisfaction is needed. Such information would help us understand the meaning of a doubling in demand, what expected consequences may be leading novices into river recreation, why new kinds of equipment are becoming popular, and why there is a desire for special river designations. Underlying this research need is the assumption that if we know about and understand the range of user demands, we will be able to prepare m agement systems capable of meeting the demands.

Second is the need to *describe the r source system.* What recreation opportuni ties is it capable of producing and how easily can it be modified to produce different opportunities? How capable is the resource system of assimilating waste pr ucts stemming from recreational and other use and how well does the environment assimilate temporary intrusive elements, li people? Also, how resistant is the resou to user-induced modification? These and similar questions need to be answered for wide range of river types and classifications. Such information would be particu larly useful in identifying the possibili ties for special designation (or resistin designation) and for resisting modificati in river flow, such as creation of lakes. This information, when combined with dema information, can also be used in meeting third research need.

This third need is to explore the pos sibilities for *developing regional system of rivers* to meet recreational demands. as expected, there are several river recre tion experiences which are demanded and th are both similar and different types of ri within a region, how might river recreati opportunities be allocated to different ri segments? In the Rocky Mountain States, instance, there are several nationally pro inent white-water rivers. Segments of the rivers are capable of providing wilderness white-water recreation. Other segments a capable of providing other types of river recreation. But how should opportunities be allocated to meet demand? A region-wi study of the rivers as a system and a stu of the demands for the region's river rec tion opportunities would produce informat useful for developing allocation models. information produced from this research w be most useful in considering special des nations and in finding rivers on which to accommodate the probable doubling of dema

The fourth general research need is *determine which management tools are effe tive in which situations and for achievin which objectives.* If managers are to eff tively deal with a doubling of demand and with a lot of users who may not be skille in recreational use of rivers, knowledge which management tools are effective is ne essary. There will not be enough time to through a trial and error process to dete

ine effectiveness on each river because the anagement demands will not wait. What is eeded is a systematic evaluation of what ractices are presently being used and an xamination of any new practice as it is mplemented. These evaluations then need o be made available to other river managers.

SUMMARY

This paper has focused on some of the nformation inputs to decisionmaking for the recreational use of rivers. Possible inputs to the three major decisions of selecting management objectives, selecting management tools, and choosing modifications in the management system were identified and discussed. Inputs presented dealt with the social, resource, and institutional (including managerial) dimensions of river planning and management. These possible inputs were then evaluated in the context of one scenario of the future recreational use of rivers to identify some categories of immediate research need.

RESEARCH FOR RIVER RECREATION PLANNING AND MANAGEMENT

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ABSTRACT.--Three research problem areas emphasizing social or people problems on rivers are described: (1) how patterns of river recreation use and characteristics of users vary on individual rivers, between different rivers, and with time; (2) how current and potential users define quality river recreation experiences; and (3) how patterns of river recreation use can be modified.

A recent article in *Northliner Magazine* referred to water as "Liquid Gold"--the basis for the multi-billion dollar tourism/recreation industry in the Upper Midwest (Sturm 1976). Similar observations have been made across the country, indeed throughout much of the world wherever recreation flourishes.

People "use" water for a wide variety of leisure activities. Many are directly water-based, such as swimming, fishing, boating, and waterfowl hunting. Other activities, such as camping, hiking, driving for pleasure, picnicking, and relaxing, are often pursued with water as an important backdrop.

The growth in recreational use of rivers and other wetlands is no surprise to those of us interested in planning and managing the leisure-use of water resources. All types of rivers--urban and rural, placid and fast-flowing, polluted and clean--are being used increasingly for recreation. Many of the papers in this Proceedings illustrate the rapid expansion in river recreation activity.

Public pressure is strong to preserve rivers and streams with high scenic, recreational, ecological, and cultural values. This is evident by the inclusion of many rivers under Federal and State river preservation programs. Principal management responsibilities for these rivers rest with the USDA Forest Service, National Park Service, Bureau of Land Management, and some State governments. Pressures to preserve more will likely continue, but not without controversy.

Some factors likely associated with the heightened interest in and use of waterways for recreation include: the seemingly crowded conditions associated with other recreational activities; the energy squeeze that has focused attention on close-to-home recreational pursuits; the reduction in pollution on many waterways resulting from legislation such as the Water Quality Act of 1965; the back-to-nature movement; the increased emphasis on physical fitness; a surge in interest by young people in challenging, even dangerous recreation activities; the growing number of books, magazines, films, and television programs on the out-of-doors and rivers in particular; and new technology in outdoor recreation equipment and related industries.

PROBLEMS RESULTING FROM GROWING POPULARITY

In spite of the manifold recreational and related *benefits* resulting from river resources, there are significant *costs*

s well. For example, frequent social and nvironmental problems have been created y the growing popularity of river recreation. Many streams are threatened by ccelerated and unregulated shoreline evelopment, which degrades water quality, estricts public access, and impairs eauty. Increased recreation use may dversely affect plants, animals, and oils along rivers. Erosion of streamanks, campsites, and landings is a ommon problem in some locations. Growing se also may result in more littering nd vandalism to public and private roperty along waterways. Problems of aintenance and law enforcement may also ncrease.

Periodic crowding on some waterways ay lessen the enjoyment of some users. ven small changes in the density or inds of river use could greatly influence he quality of experiences for some isitors. In fact, people seeking low-ensity use and contact with nature may e displaced altogether. Conversely, rowds appeal to some people (Bultena nd Klessig 1969 , Clark *et al.* 1971). ertain river users may also enjoy the ociability afforded by crowds.[1]

Recreational use often generates ther conflicts in addition to crowding. onflict has arisen between fly fishermen nd boaters (Bassett *et al.* 1972 , river and Bassett 1975), between motor-zed and nonmotorized boaters (see Nielsen nd Shelby paper in this Proceedings and helby 1975), and between recreationists nd landowners.[2] As use increases, onflict will probably grow and so will ebate over how to curb such conditions.

Probably the most serious and mmediate river management problems nvolve conflicts within and between ecreation and nonrecreation uses.

These problems are changing fast, faster than techniques can be developed to cope with them, and probably faster than changes to the natural, biological system resulting from recreation use. Unfortunately, less is known about river use and users than about user impact on the physical resource (Stankey and Lime 1973).

In the absence of documentation about river recreation use, many decisions have been made intuitively by recreation planners and managers to minimize problems and to maintain quality recreation opportunities. Use rationing, limitations on camping and open fires, party-size restrictions, limitations on lengths of stay, and other use restrictions have been imposed or are anticipated on many waterways. Some management strategies seem to have worked well and have gained public support; others have not. Managerial actions frequently have been reflected both in dissatisfied recreation users and in litigation by a variety of river recreation interests.

THE RIVER RECREATION SYSTEM

The river recreation "system" is complex and many faceted. There are several key elements of concern to river recreation planners, managers, researchers, and often the public:

1. *The River*, which has both recreation and nonrecreation functions
2. *The Adjoining Land*, land in the river corridor and further removed that is part of the recreation environment and is impacted by recreation use, directly or indirectly
3. *The River Recreation User* (or potential recreation user), which includes both river and river corridor users, such as canoeists, fishermen, hikers, hunters, and cottage owners
4. *Nonrecreation River Uses* such as commercial fishing and trapping, transport, hydropower and irrigation, water supply, and waste-water treatment, that may conflict with recreation use of the river
5. *Nonrecreation Riparian Uses*, such as forest industry, mining, agriculture, and residential land use, that may benefit from recreation use (as in

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[1]*Habermehl, James M. 1973. Deter-ining visitor perceptions of crowding n the Ozark National Scenic Riverways. 3 p. Unpublished M.S. Thesis, Univer-ity of Missouri, Columbia.*

[2]*Wehunt, Eugene P., Jr. 1971. andowner's perception of recreationist ssociated conflicts in the Salmon-ittle River corridor of Idaho. 104 p. npublished M.A. Thesis, University of daho, Moscow.*

the case of local economies) but may conflict with recreation use of the river

6. *The Nonriver User*, who nevertheless is interested in the river, directly or indirectly (e.g., vicarious users), as a public resource

7. *The Entrepreneur*, who makes a living directly or indirectly from river recreation

8. *The Planner and Legislator*, who is responsible for assessing national and regional patterns of recreation resource needs

9. *The Manager*, who is responsible for onsite management to protect both physical resources and experiences of visitors

Some special features of river recreation resources that pose unique problems for effective management and research are: (1) the linearity and directional character of river corridors, (2) multiple access and egress points, (3) fragmented jurisdictions or absence of responsibility by any agency, (4) impediments to observing and monitoring resource change and user behavior throughout the system, and (5) the high degree of variability and irregularity in recreation use and in resource conditions of the river itself.

NEEDED INFORMATION ABOUT RIVER RECREATION SYSTEMS

Planners and managers of river recreation environments need better information to properly evaluate alternative ways of managing resources to provide the range and mix of experiences sought by visitors and to protect the physical environment. Below are nine types of information that would help in defining administrative objectives and guidelines:

1. *Classification of rivers as recreation resources*.--Taking into account physical, cultural, historic, and perceptual attributes, how can rivers and river corridors be classified as to their recreation potential? What physical attributes (e.g., instream flow, accessibility, soil, and vegetation) influence specific recreation activity patterns on rivers and adjacent land? What attributes of rivers do recreation planners, managers, and users believe to be important? What methods can be developed to synthesize and display such data for analysis and interpretation?

2. *Patterns of river recreation use*.--How do patterns of river use and characteristic of users vary on rivers, between rivers, and with time?

3. *A view of future river recreation use*.--What activities, use patterns, and user characteristics can be expected in the future?

4. *Understanding river recreation behavior and experiences*.--Why do people participate in river recreation? What influences patterns of river use? What conditions provide optimum satisfaction and benefits for users? What do river recreation users actually experience?

5. *Impacts of use on user experiences*.--What are the effects of various amounts and types of recreation use on the experiences of users? How is the experience sought by users influenced by (a) conflicts between various types of users, (b) the relative naturalness of a river, (c) consumptive uses and shoreline development (logging, mining, agriculture, private residences, etc.), and (d) availability of developed facilities such as campsites and landings?

6. *Impacts of use on physical resources*.--What are the effects of recreation and nonrecreation uses on physical resources, such as water, fish and other wildlife, soil, vegetation?

7. *Impacts of river recreation on economics and other social values*.--What are the effects of recreation use on local, regional, and perhaps national economies? Can methods be developed to assess the "value" of recreation experiences in relation to costs and benefits of alternative river uses?

8. *Managing physical resources of rivers*.--What management techniques will work best to minimize change in physical resources within acceptable limits?

9. *Managing experiences of river users*.--What management techniques will work best to improve the experiences of recreation users? What management systems

ill ensure a diverse range of river ecreation experiences that transcend dministrative and jurisdictional oundaries?

SOME GENERALIZATIONS ABOUT RIVER RECREATION RESEARCH

There has been a recent proliferation f literature dealing with river recrea- ion (as witnessed by the Literature ited at the conclusion of this Proceed- ngs). Nonetheless, serious voids re- ain in the information-need areas escribed above. Some reasons for this re that much of the research has:

1. Involved one-time studies without ollowup research, resulting in unique, ncomparable data
2. Consisted of one-river case tudies devoted primarily to understanding ocal conditions, again limiting generality
3. Been poorly designed in terms f limited sample size, representative- ess, and methodology
4. Emphasized description rather han detailed analysis of processes and pecific interrelations
5. Focused on studies of a single iver activity at one time of the year usually summer)
6. Documented only on-water activi- ies (e.g., canoeing, rafting, fishing) nd ignored riparian recreation users
7. Been conducted on Western white- ater rivers that are unique both in ocation (usually remote from urban enters) and management (usually desig- ated as a National Wild and Scenic River within a National Park or Monument)
8. Been partially analyzed and/or naccessible in that much of it is buried n environmental impact statements, gency management plans, informational amphlets for specific rivers, Statewide utdoor recreation plans, academic issertations, and unpublished manuscripts
9. Been funded and/or encouraged by and managers who frequently want one-time, ne-river, single activity, descriptive tudies that reflect local conditions. eldom has research been funded to system- tically study regional, even basin-wide ivers as a system so recreation uses can e better planned and allocated to reflect he mix of experiences desired by the ublic.

USDA FOREST SERVICE RIVER RECREATION RESEARCH

To assist in the general quest for information to aid river recreation planning and management, social scientists at the North Central Forest Experiment Station, St. Paul, Minnesota, are embarking on a new program of nationwide research on *backcountry* river management. *Backcountry rivers* range from virtually undeveloped, such as those located in the National Wilderness Preservation System, to those traversing agricultural or urban landscapes that nevertheless offer the recreation user a feeling of being in a relatively wild setting (Lime 1975a).

The Station's river recreation research project is particularly interested in the broad problem of managing river recreation systems to optimize visitor enjoyment, consistent with the limits set by management objectives, of course. Consequently, the research is oriented toward the study of human behavior under various river settings and conditions--the source of the "people problems" with which management increasingly must deal.

Although much of the river recreation research will be conducted in the Station's Upper Midwest territory, some studies will be carried out in other parts of the country. Through cooperation with various Federal agencies, universities, and State and local governments responsible for river planning and management, many opportunities exist for research in a broad range of disciplines. Some research has begun and plans for future studies are being made. The uncertainties of a new field will require that research plans be flexible enough to incorporate change.

The Station's recreation research unit will focus on selected research topics under the following three questions:

1. How do patterns of river recreation use and characteristics of users vary on individual rivers, between different rivers, and with time?

2. How do current and potential river users define quality river recreation experiences?

3. How can patterns of river recreation use be modified to achieve specific management objectives?

Answers to these questions will help provide, directly or indirectly, the nine types of needed information described earlier.

Patterns of Use and Users

Recreation planners and managers need to know *how* and *by whom* riverscapes are used. In a sense, basic descriptive information is analogous to timber and range inventories. In both instances, the data allow analysis of supply and demand relations, aid in facility planning, and assist in the development of regulatory and informational programs. Such data can also be used to supplement environmental impact statements and river classification studies, to aid future use projections, and to determine how management programs alter patterns of use.

A specific objective of this research is to develop comprehensive descriptive profiles of who the recreation users are and how they behave, both toward the environment and toward each other. River recreation users will be studied to determine their demographic characteristics (e.g., age, sex, occupation, residence); social characteristics (e.g., group size, social behavior, spatial tolerance); location-of-use characteristics (e.g., access, egress, intra-river activity, campsite locations); time-of-use characteristics (e.g., time, frequency, and duration of visits), and recreation activity characteristics (e.g., activities, kinds and sources of equipment, previous knowledge and skills).

As an important early step in this research, we plan to develop a classification system for river recreation resources that incorporates environmental, experiential, and managerial variability. The classification scheme will consider variations in: (1) environmental features and human use of rivers (e.g., streamflow characteristics, water quality, geographic location, corridor land uses, ease of access), (2) social, demographic, and psychological conditions that distinguish or characterize individu users and groups of users (e.g., use densities, sources of conflicts, residence, age, occupation), and (3) current and proposed management activities (e.g., site and facility management techniques, regulation of use). Such informa tion will facilitate the selection of rivers for study so as to maximize research on a wide range of use conditions and river settings. It also could permit a more logical extension of resear results from river to river.

Standardized data collection systems need to be developed so that followup studies on sample rivers can be made at appropriate intervals. Ideally, such recreation participation surveys would focus on *specific* river-related activitie and would be conducted at the State, regional, and even national level to allow maximum comparability both within and between river systems.

Through such repetitive studies, it would be possible to answer such questions as: (a) Is the amount of use changing? (b) Are use conditions or activities shifting? (e.g., does fishing use drop off as canoe use grows?) (c) Are certain access points attracting more groups or more of certain visitor types than others? (d) Is the use season expanding into spring, fall, and winter? and (e) Is the river assuming greater significance as a regional or national attraction because more people are coming from greater distances?

The Station's recreation research project currently is involved in several efforts to describe the current state-of-the-knowledge regarding river recreation. An annotated bibliography of river recreation literature containing more than 200 citations has been completed.[3] Also, as noted above, a river classification scheme is being developed to identify key characteristics of selected recreational rivers in the United States.

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[3] *Anderson, Dorothy H., Earl C. Leatherberry, and David W. Lime. (In prep.) An annotated bibliography on river recreation. Manuscript on file at North Central Forest Experiment Station, St. Paul, Minnesota.*

Some research is planned or underway o develop better use measurement and onitoring systems. Michael Chubb of ichigan State University is cooperating ith us on a study to test methods for stimating the geographic distribution f river use on several rivers in ichigan. He experimented with several utomatic recording devices in conjunction ith onsite visitor interviews. In a econd study in Michigan, Chubb and auman developed a preliminary method o quantitatively classify a river's ecreation potential for 16 different ctivities.[4]

With other research cooperators, we re testing methods to accurately measure he attitudes, activities, and back-round of sample populations of river ecreation users. Studies are ongoing r completed on the Green (Desolation anyon) and Colorado (Westwater Canyon) ivers in Utah by Richard Schreyer of tah State University and on the Kettle iver in Minnesota by Lawrence Merriam, r., and Timothy Knopp of the University f Minnesota. The results of these and ther methodology studies will be useful n later more comprehensive studies of variety of rivers. We currently are lanning a 1977 study of use and users f selected rivers under Bureau of Land anagement administration.

Although our program must be flex-ble, some plans for future studies nclude: (1) further descriptive studies nder a variety of recreational use onditions and river settings through-ut the country; (2) a series of studies o test use measurement and monitoring ystems such as aerial and ground photo-raphy, "electric eye" counters, and bservation; (3) an indepth study of iver activities and backgrounds of egistered boat owners in Minnesota; and 4) a study of urban-suburban river ecreation use patterns in the Upper idwest.

efining Quality Recreation Experiences

Resource planners and managers must efine appropriate administrative objectives to accommodate the wide range of possible recreation uses for rivers. To aid in evaluating alternative objectives and management strategies to implement objectives, better information is needed about how present and potential users define quality river recreation experiences. To do this, resource administrators must know more than they do now about the motives that prompt people to participate, or not participate, in river recreation activities. We need to identify the range of activities people desire and the specific attributes of river environments and recreational use conditions that provide optimum satisfaction and benefits for them.

Such research must commence with appropriate measurement techniques and instruments. Some methods exist, but many will need to be developed to fit the specific questions and conditions under study. Such methods will need to measure the expectations, perceptions, awareness, behaviors, feelings, and moods of different recreational user groups across a spectrum of riverscape settings. River settings should be chosen to permit contrast among factors having major influences on recreational participation and satisfaction.

One application of such research methodology lies in refining the concept of *social carrying capacities* of rivers; that is, the amount and kind of use an area can support over a specified time without causing unacceptable change to the recreational experience (Lime and Stankey 1971). Such research would reveal how experiences sought by river users relate to: (a) amounts and distributions of use, (b) conflicts between various user groups, (c) commercial and other developments (mines, farms, factories, private residences, etc.), (d) level and extent of managerial intervention (campsite development, access point control, etc.), (e) type and abundance of flora and fauna, and (f) physical characteristics of the river (length, velocity, temperature, purity, etc.). Research should include both studies of present river users and studies of nonriver users to identify what prevents some people from participating in these activities.

These investigations should relate to and benefit from research on patterns

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[4]*Bauman, Eric H. 1976. A method or assessing river recreation potential. 88 p. Unpublished M.A. Thesis, Michigan tate University, East Lansing, Michigan.*

of use and users (described previously). An understanding of the decisionmaking processes and factors that shape users' decisions can also help determine how patterns of use can be modified.

The Station's research project is cooperating with social scientists from several universities to measure and evaluate how recreation users define quality experiences. Results of some of this research are reported in this Proceedings by deBettencourt and Peterson, Driver and Bassett, and Cherem and Traweek. Attempts to develop similar research methodology are included in the objectives of Schreyer's study on two rivers in Utah described earlier. Major outputs of this research will include profiles of what motivates various users to visit rivers and their preferences for particular river settings, types of facilities, and use-management strategies.

Our plans for further research in this area include: (1) more indepth studies to develop research strategies and instruments to identify basic satisfactions and benefits of river recreation experiences and to test promising methods on a spectrum of river settings, (2) further studies of social carrying capacities and how use affects the quality of experiences, (3) more indepth studies to identify factors that influence how users choose rivers or certain sections of rivers for recreational pursuits, (4) a preliminary study of satisfactions resulting from nonhunting wildlife encounters on rivers, and (5) a study of river managers' perceptions of how river *users* define quality experiences and respond to use-management techniques.

Modifying River Recreation Use

The third research area focuses on developing management techniques to accommodate the wide range of river recreation uses, while minimizing the conflicts that often arise between various interests. Of course, techniques are needed that do not violate the objectives prescribed for the riverscape under study. These objectives limit the options available to the planner or manager, but often there are several alternatives to solve a given problem.

Studies are needed to determine how various publics feel about techniques to control, modify, and redistribute use, and to identify opinions about site management techniques to minimize physical resource damage (Lime 1976). For example, how do people react to regulatory management techniques (e.g., reservations, limits on party size and lengths of stay, zoning compared to manipulative techniques (e.g. information, fees, changes in access points)?

Studies also are needed to determine the impact of potential use management policies on the *behavior* of users because what people say they want may not be reflected in what they do. For example, studies in cooperation with river managers could measure changes in user behavior and experiences in response to varying methods to schedule daily use limits at river access points (see the Nielsen and Shelby paper in this Proceedings).

Additionally, studies need to focus on finding more effective ways to communicate with recreation users to enhance their outdoor experiences. Through studies of how users choose among alternative river activities and locations, further research can determine what information can best help them find areas that match their desires, expectations, and skills.

Related research is needed to determine how the destructive and inconsiderate behavior of some river users can be reduced. Some of this behavior undoubtedly results from people not understanding the full consequences of their actions, rather than from overt maliciousness. Attention should focus on identifying better ways of educating users to understand and appreciate the effects of their actions on the environment and on other users, and to provide users with the skills necessary to reduce adverse impacts. Communicative techniques are also needed to explain management objectives and the need for restrictive measures to protect river resources and visitor experiences.

One current study by our river recreation project is focusing on how and to what degree visitor distribution can be altered by information supplied to visitors. In the Boundary Waters Canoe Area of Minnesota, we are studying (in cooperation with Robert Lucas, Inter-

ountain Forest and Range Experiment Station) the extent to which information about patterns of use, attractions, and other factors can alter visitors' choices of routes, areas, and times of visit. Information supplied to visitors seems to be a highly desirable management technique because it is less authoritarian or regulative than many other techniques (e.g., restricting access).

Other research by the Project is focusing on a field test of the Wilderness Area Simulation Model (Shechter 1975) in a river recreation context. The Simulator provides a measure of the number of encounters (visual meetings) river parties have with other parties and the locations of these encounters along the river corridor (on the water, at rapids, at campsites, etc.). The method has been tested in a recent study in Dinosaur National Monument (see McCool, Lime, and Anderson in this Proceedings). An extension of this research is planned for 1977 for the Selway River in the Selway-Bitterroot Wilderness in Idaho. In related research, George Peterson of Northwestern University has cooperated with the Project on several studies to simulate visitor travel in the Boundary Waters Canoe Area (see Peterson *et al.* in this Proceedings).

Our future research plans include: (1) additional studies to determine users' attitudes and behaviors toward various regulative and manipulative use-management techniques in a variety of river recreation situations, (2) an indepth study of user attitudes toward existing use rationing programs, and (3) a preliminary study of depreciative behavior by river recreation users and ways to control it.

CONCLUSION

Information about the use and users of river resources seems woefully inadequate. Even for rivers supposedly "known" for heavy use, unhappy users, and resource deterioration, little is known about how these riverways are used, by whom, and what users are seeking in outdoor experiences. Much social research in designated Wilderness Areas, at reservoirs and lakes, in highly developed and concentrated recreation areas, and in other places has focused on many of the same questions raised here. However, it would be premature to assume that such results would have direct application to river recreation planning and management.

The availability of a wide variety of rivers and streams for recreation has, indeed, provided new and expanded opportunities for many people throughout North America. At the same time, such growth has caused critical management problems demanding thoughtful solution. In order to improve planning and management of river recreation use and to better evaluate management decisions, a host of recreation and related research needs are evident. There are unique and challenging opportunities for scientists from all disciplines to cooperatively apply their interests, expertise, and creativity to solving these problems.

ACKNOWLEDGMENT

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CITIZEN GROUPS: THEIR ROLE IN RIVER RECREATIONAL PLANNING

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ABSTRACT.--The two equal and essential components that the river recreation planner must consider in decision-making are the managed space and the user who will inhabit that space. River user conflicts arise as the result of territorial interests of citizen groups. Although the conflict between specific recreational users can never be fully resolved, the resource manager can adopt certain attitudes and actions to mitigate the conflict.

In order to understand the role of citizens in river recreational planning, it is necessary to understand the basic motivation behind their interest in the river. This motivation is based on a concern for the utilization of space that conforms to specific needs or perceptions. These needs and perceptions form the nucleus around which various citizen groups coalesce. The different aspirations, visions, or legitimate fears act as a bonding agent that is critical to group formation and stability because without it these groups would soon fragment.

The concern of citizen groups generally centers around one of two types of issues: image and space. This paper will deal only with the second type of issue--the utilization and competition for river recreational space.

Concern for space as a behavioral characteristic can be justified in a number of psychosocial ways; as a basic human drive concerning economics, self-identity, history, safety, health, or power. However, it will suffice here to describe this trait by reference to the territorial drive and sense of identity of the human being.

In the case of territoriality, the individual or group becomes familiar with, adopts, and utilizes space. If the individual's or group's use of the space is highly specialized, they feel threatened by any changes made to the area. If the individual's use of the area is not particularly specialized, or if it is not readily applicable to his type of specialty he may seek ways to improve the area to make it more attractive to his use. This type of activity is called environmental modification and every animal does it to the degree which its ability and needs permit.

CONFLICTING PUBLIC DEMANDS

Obvious conflicts can occur between two groups when they utilize the same space or resource for different uses. This conflict is further compounded when the individual or agency legally controlling the area and the resources found within it is brought into the picture. He has responsibility for its long-range management and is faced with the decisions of what types of change or no change to allow to occur.

No matter what management decisions are made, they will have some impact upon people who pass through, visit, or pass in close proximity the managed area.

In the private sector of space management, the businessman needs only internal justification of his decisions and need not worry about external groups or organizations, unless his management areas are very large or his decisions carry a high degree of public risk (i.e., nuclear

ower plants, toxic chemical plants, etc.).

However, when managing public space, ur laws require that decisions be based n the good of the public and that citizens ave a voice in the decisions. Unfortunate-y, the citizens' voice is never unified. here is no "public" speaking with a single oice who can give a general thumbs up or own to public management decisions. nstead, there are many citizen groups, ach with its own ideas, fears, and esires concerning how and when changes hould occur.

The conflict over river use is joined t two levels. The first is a general evel dealing with allocation of the river nd its watershed for general uses such as ecreation, water supply, sewage dilution, imber production, streamside sites for omes, etc. It is determined at this evel of conflict whether recreational, conomic, or some other use prevails. The econd level of conflict comes into play hen the specific types of a general iven use are worked out among citizen roups, private sector users, and managers; or example, the specific types of ecreational use.

ITIZEN RIVER RECREATIONAL PLANNING GROUPS

Historically, in river recreational lanning, three major types of citizen roups present themselves. They are the nonspecialized users", the "specialized sers", and the "preservers". Conflicts ver appropriate river recreational use an occur as a result of these three ifferent perspectives. For example, such pecialized groups as canoeists might ppose major projects that would facili-ate flatwater sports, fishing, motor oating and picnicking, yet support some mall access-point improvements that ould mean easier ingress or egress from he stream for them. At the same time, he preservers might be opposed to all f these improvements.

The conflict between different recre-tional user groups can be very dishearten-ng and frustrating to the manager. He must ake decisions that gain him friends and upport from one group but cost him friends nd support from another. However, there re attitudes, measures, and techniques the river planning manager can adopt to ease or eliminate the bad feelings associ-ated with decision-making.

USES OF AN INFORMATION OFFICER

Probably the biggest asset to an agency in dealing with citizen groups is an information officer who truly believes in the involvement of citizens in the planning and management of their resources. If the official and his agency are not committed to citizen involvement, they may delay involving citizens in the planning process until the process has moved toward an image of the agency's wants. In addition, people can sense the insensitivity of officials not dedicated to the concept of citizen involvement.

EARLY CITIZEN INVOLVEMENT

Courage and self-confidence on the part of the planner and public officials are required if early involvement of citizen groups is to work. The concept of developing citizen input over an extended period basically goes against professional character, which dictates that the pro-fessional himself must produce something. Professionals feel that if they do not initially provide for a finished product, or at least know what they wish to accomplish, they are open to ridicule for not knowing their job. A professional must be courageous in the sense that a ship's captain must be courageous to set sail on an exploratory trip without any clear idea of where he is sailing.

When citizens are involved in a study that has no preconceived idea of what con-clusions will result, the official runs the risk of losing control of the study and spending huge sums of money without accom-plishing any clearcut objectives or of producing a totally unrealistic or unacceptable plan. However, if he can incorporate citizen input throughout a study and derive a workable plan, the rewards are great. If the citizen groups identify with the study, they can be a powerful force to aid in regulating, legislating, raising funds, and lobbying for long-term project maintenance. They can also help to combat any opposition that might arise late.

THE CHATTOOGA EXAMPLE

When it first became apparent that the Chattooga River would be considered as a National Wild and Scenic River, the USDA Forest Service began to involve the local residents, conservation groups, and other groups into the planning process. This early involvement forestalled a lot of antagonistic interactions, even though there are elements in the final plan that are not agreed upon by all.

One of the more interesting aspects of the Chattooga plan was the incorporation of commercial recreational users. This group was incorporated into the planning process and the design of the commercial contracts was based to a large extent on this and the conservation groups' input. The primary goal here was to keep commercial operation at a level that would not interfere with private recreational use. Commercial use of the river today is about 30 percent of the total use of the river corridor.

HUMAN FLEXIBILITY

Flexibility in human behavior is one of the major factors that can make good planning and plan implementation a reality instead of a pipe dream. A good example of a management program that resulted in extended multiple use and in cooperation between disparate user groups is the Hiawassee River in Eastern Tennessee. The Tennessee Valley Authority published water release schedules that told local fishermen what hours the stream flow would be low and suitable for wading. The schedules also tell canoeists and rafters the times that they can get the best rides so that they can plan their launch times.

CITIZENS AS A VALUABLE RESOURCE

Another important aspect of citizen input is their utilization as an important resource to assist professional staff in conducting research and physical surveys. By locating and utilizing active users, some of whom are experts in related recreational and nature study fields, public officials can incorporate useful data into the plan that will enhance use or avoid costly mistakes. For example, citizen involvement can aid in the proper location of recreational use areas. This can be exemplified by a discussion of the two choices a resource manager faces when he first decides to improve an area. There are two traps he can fall into in placing campsites or other recreational use facilities. One trap is to place the facilities where current use is not already occurring and the other is to place the facilities where current use is already occurring. This may seem mutually contradictory, but it can be explained by citing an example.

If, for instance, the recreational facility is not located in the areas where they logically fit with the use schedule, even though they might be attractive, they will probably not be used. We saw this on the Chattahoochee River in Atlanta. In this case, public launch points were provided but the users insisted on trespassing on private property to launch their rafts, canoes, and kayaks because the public use areas were: (1) not located in such a way as to enable them to take a good day trip; and (2) were not located over the segments of water the people desired to use.

The problem could have been avoided by citizen input.

If the facilities are located only where the use is presently occurring and other considerations such as soil type, geological suitability, vegetation cover, and citizen input are not considered, a badly damaged environment can result from overuse. A situation of this sort occurred with the placement of Chimneys Campground along the Little Pigeon River near Gatlinburg, Tennessee. Chimneys Campground began as a trail into the woods for backpackers. The trail was eventually upgraded into a dirt road and people began camping there out of the back of their cars. This soon developed into a looped gravel road and car camping became heavy. The road was next paved and gravel sites were put in for trailers and amenities provided. Finally, so much of the area was altered that during heavy rains flooding essentially destroyed the whole area to the degree that efforts have now been made to convert the site into day-use picnic area only.

In this case the site was simply not suitable for the high intense recreational

se which was encouraged to develop. nvolvement of citizen groups in the ecisions that led to this situation ould well have avoided the impacts be- ause many of the original user groups ere opposed to any upgrading of the area s a result of their familiarity with it. his also illustrates that the desires nd actions of the majority of the citizen sers may not always be right and in a ase like this, it is up to the profession- l to point out potential consequences.

SUMMARY

Although I have dwelled rather eavily on the need for citizen involve- ent at the beginning of a project, there s an equal need to continue that involve- ent into and beyond the completion of the roject. It is important that at the eginning of a project, both potentially upportive groups and potential adversaries hould be identified and their input solicited without a preconceived notion of who is right and who is wrong. Then by mutual dialogue and arbitration by the professional staff, it is possible to resolve conflicts and allow for flexibility in final implementation. If this is accomplished and if the citizen groups can claim some pride of ownership in the plan, they can be a strong force in securing funds and other backing. Citizen input and review in the detailed plan development can aid in avoiding placement of facilities in areas where they are not suited or will not be used. Finally, continued citizen feedback after full implementation has been accomplished is necessary to keep track of user behavior changes, environmental changes, misuse and abuse of facilities, or to identify mistakes made during the planning phase. Only by this continued monitoring and feedback mechanism can the planner and manager continue to provide the facilities that will result in a good, clean, safe recreational environment for the citizen.

COMMERCIAL RIVER OUTFITTING: ITS EDUCATIONAL ROLE AND RESPONSIBILITIES TO THE FUTURE

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ABSTRACT.--Two trends are postulated: (1) a decrease in the rate of demand for commercial outfitting services, and (2) increase in demand for "do-it-yourself" trips. The competition between commercial outfitters and private groups on restricted rivers is explored. Commercial outfitters can be justified for both their "educational" and "public access" services; the outfitter who so justifies his existence can enjoy a greater freedom from worry over future survival.

As managers and commercial outfitters we share a common mandate: to protect the resource and to provide the public with the best possible recreational and wilderness experiences that can be provided, now and in the future.

I have asked more than 20 of my colleagues over the phone and in questionnaires what their feelings are about the future of commercial river running activities. Some of the major trends they identified are in the following pages.

A DECREASE IN THE RATE OF DEMAND FOR OUTFITTER SERVICES

The demand for public outfitter services is decidely on the rise, but the rate of increasing demand for outfitter services will taper off in the next several years if it hasn't already. Several of my colleagues feel the rate in some areas has peaked and that demand is bound to level out. It is difficult to get a true measure of demand. My assumption of a decrease in the rate of demand is based on a closed market system, i.e., visitor use ceilings, but without any effective price regulations to date. This means that supply has been curtailed to protect the resource while prices in most areas have been allowed to increase to the point that the demand greatly in excess of supply has been stifled.

It is easy to suggest that if supply were not a problem or prices were controlled, the rate of increasing demand would again rise. There are demands for commercial outfitting, however, of two basic types: the guided tour kind where everything is done for the client including ice in his cocktails and staff to set up the tents and cots; and the kind in which individual participation (from helping in the kitchen to paddling one's own craft) is encouraged or even instructed. The first kind will fall off long before the do-it-yourself kind.

A CONTINUING INCREASE IN THE DEMAND FOR DO-IT-YOURSELF OUTINGS

It is safe to assume a continuing increase in the rate of demand for do-it-yourself outings as evidenced by several other papers presented at this symposium. The rapid increase in private permit applications in the Grand Canyon and other areas is further evidence of this trend. (I hesitate to cite the statistics since it is suspected that several individuals from the same proposed river party would apply in order to increase their chances of obtaining a permit.)

I intend to discuss private, do-it-yourself use, only as it competes with commercial outfitter services. In the light

of decreasing rate of demand for outfitter services but an increase in do-it-yourself outings, how do we determine priority among competing users? If priority use cannot be established, how will competing uses be apportioned?

A JUST ALLOCATION BETWEEN COMPETING USER INTERESTS

In the years ahead it is hard to imagine that most river recreation areas under discussion at this symposium won't be under some system of use restriction, with a certain portion alloted through commercial outfitters and another portion to "do-it-yourselfers". To date the ratio between these competing interests has been determined either by past use in a given year or is arbitrarily chosen. Examples are the Grand Canyon with a 92:8 (commercial to do-it-yourself) split, the Selway with a 20:80 split, and most Bureau of Land Management (BLM) administered lands in the west at 50:50. Clearly, conflicts between these two user groups will become more and more intense.

THE WILDERNESS PUBLIC RIGHTS FUND POSITION

The Wilderness Public Rights Fund (WPRF) is an organization that was formed in 1975 to advance the interests of the "do-it-yourself" user. "It is WPRF's contention that, when commercial and noncommercial user groups are required because of government edict to compete for the same public space, the qualified noncommercial category must be given priority" (Saltonstall 1976). WPRF bases their contention on their interpretation of the Concessioners Act (P.L. 89-249, 79 statute 969): "...no natural curiosities, wonders, or objects of interest shall be leased, rented, or granted to anyone on such terms as to interfere with free access to them by the public... (16 U.S.C. Sea. 3)" and "it is the policy of the congress that such development shall be limited to those that are necessary and appropriate for public use and enjoyment of the national park area in which they are located and that are consistent to the highest practical degree with the preservation and conservation of the areas" (Saltonstall 1976). WPRF does *not* necessarily assert that public noncommercial users have an unqualified "priority of right". However, they do feel that "concessioners profiting by use of public lands as their major capital resource are legally obligated to be the first to prove how, when, and where their services are unique or essential" (Saltonstall 1976).

THE WESTERN RIVER GUIDES ASSOCIATION POSITION

The opposing view is perhaps best represented by the position of the Western River Guides Association (WRGA) through its Private Permit Action Committee (PPAC) formed in 1974 for the purpose of drafting a position statement regarding commercial vs. noncommercial use. The seven-person committee was formed of three public outfitters, three private river runners (one of whom has guided actively for commercial outfitters) and one representative of the National Park Service. The committee's first recommendation (unanimously approved) follows (PPAC 1974):

"Qualified commercial and noncommercial river running are forms of legitimate public use of our national resources. Both serve the national interest; therefore, commercial and noncommercial use should co-exist on runnable rivers, neither to the exclusion of the other."

Roderick Nash, committee member, introduced a concept for consideration which has provoked much thought and discussion among outfitters and managing agents but which was not acted upon (PPAC 1974).

"The percentage of disappointment (or demand excess) should be the same on a given river in a given season for both commercial and noncommercial users. For example, if 3,000 qualified noncommercial persons applied for a permit but ceilings and allotments permitted only 1,000 to run, the percentage of disappointment is 2/3 or 67 percent. To justify such a denial there should be documented evidence that this same percentage of disappointment existed for commercial users."

And how do we go about measuring demand? The PPAC has suggested, "Paid deposits would suffice to document commercial demand; but commercial outfitters are unwilling to deliberately stimulate deposit payments greatly in excess of their allotment as they might be required to do in the

event of a high percentage of disappointment in the noncommercial sector" (PPAC 1974). "Outfitters can hardly be said to be competing for customers when most of their trips are filled six months or a year in advance [in the Grand Canyon]; there is no point in stimulating demand which already exceeds supply" (Litton 1976).

The noncommercial private river runners of course are quick to raise the question, "How much (of the commercial demand) is in part artificially created by widespread colorful advertising?" (Saltonstall 1976). Even though three of the largest commercial outfitters in the Grand Canyon have personally indicated to me that their advertising budget is less than 2 percent of their gross receipts (exceptionally low in comparison to most private industry) the private runners have a point: it would be almost impossible to quantify to what extent "artificial" demand plays a part in the total demand picture.

By the same token it would be almost impossible to quantify to what extent the demand factor for private permit applicants is artificially inflated through multiple applications from several individuals all intending to run under the same permit--whichever permit happens to come through. I personally know of 3 different private groups applying for Grand Canyon permits in 1976 which abused the system in the manner suggested. One individual told me everyone in his group of 10 applied for a permit; 9 were denied and 1 was granted. The system invites abuse; no one denies that.

One other interesting consideration that further muddies the issue is that many private runners were first introduced to the sport through participating in a commercial outing or through attending a "white-water school," many of which are sponsored by commercial river companies.

ACCOUNTABILITY AND PROTECTING THE RESOURCE

Who protects the resource more, the private user or the public outfitter? It is a tough question and there is no documentation that I know of which even suggests one category of user harms the resource more than the other. So we are down to who may be more easily held accountable for the resource.

Here are two opinions: (1) "I believe the commercial outfitters are more careful about using the river resource. There is an accountability factor that is present with the commercial rafters that is missing with private boaters. I am afraid that if we turn over our rivers to the private user then we will lose them through abuse" (Huser as quoted by Evans 1976).

(2) "Public outfitters whose success in business depends, among other things, on maintaining tidy campsites, are at the same time under constant scrutiny by the controlling agency as well as by their clientele. It is easy for the [regulatory agency] to determine how an outfitter is treating [the resource], difficult to learn how private users are treating it, and next to impossible to penalize private users, after the fact, if indeed blame for misuse can be established" (Litton 1976).

I would like to add my own opinion--with a slightly different slant--in support of these two. I wouldn't consider most outfitters worrying about being under the scrutiny of their clientele so much as concerned about their responsibility and the unusual opportunity to educate their clientele to be more concerned about protecting the resource. Personally, I have found on numerous outings in the Grand Canyon and elsewhere that the trip participants seem unusually receptive to the example we set. They respect our point of view; they are generally impressed with how tidy a place the Grand Canyon is. They are a captive audience, and they go home with a little firmer resolve to emulate our care for the environment.

One of my colleagues carried it a step further. "We are a buffer between the public and the land. More and more I think an outfitter's justification is in generating and sustaining public sympathy against consumptive, destructive, energy intensive uses of the outdoor environment."

I am not suggesting, however, that the issues raised by the accountability problem should necessarily contribute to increasing or decreasing any one type of user's share of the river wilderness. Ultimately, accountability and protection of the resource is an adminstrative problem solved through greater education (by the agencies and the outfitters) and enforcement. Huser has suggested, as an example of one solution,

at "anyone who goes into the wilderness ould have a wilderness use license. It uld be much like a driver's license. is would not stop abuse, but it would esent an accountability factor" (Evans 76).

PRIORITY FOR MODES OF TRAVEL--NOT ACCORDING TO MEANS OF OUTFITTING

I believe priority should be based on de of travel, not on whether the party is commercially outfitted or a privately tfitted group. There are places where torized travel should and should not be lowed. Motorized travel should be pro-bited at the point at which there is mage to the resource or undue compromise the wilderness values of a significant rtion of users within an area of otherwise stinct wilderness character. At some int this calls for value judgments, urage to make those judgments, and (in-nveniently at times) the law to back them . I do not believe priority for using area should be based on whether a user commercial or private. If private use re favored over commercial use, there is e potential for completely excluding from e resource that portion of the public ich lacks the capability for "doing-it-emselves". Those excluded might not have own someone with the requisite experience, might not have had the time nor money develop the necessary experience and ass the necessary equipment.

Let me explain further, again using e example of the Grand Canyon. Commercial d private users jointly expend about ,000 passenger-days (p/d's) in a ratio 92/8 percent respectively. Assuming a ntinuing increase in demand by both types users, it is theoretically possible ome years hence) for private use to equal ,000 p/d's even though in that same year is theoretically possible (with the re-xation of all but cost constraints) for mmercial demand to equal 300,000 p/d's presenting a valid use of the resource ich would be wholly frustrated. This tuation would be totally unacceptable to , not just because I am a commercial out-tter but because of all the excited, happy ople I have seen come off of river trips o have said, "I came expecting a good me, but have come away with so much more an I ever thought possible." Their out-ok has been expanded in a very subjective way that has a special meaning for them. Something has opened them up--the guides, the resource, or whatever--and made them receptive to the full breadth and depth a river experience has to offer.

That leaves us at a standoff, but with the need to do a lot more research on the private vs. commercial issue. For one thing, we need sound data on demand and use ratios (PPAC 1974). How do we get this in-formation? Some ways might be through measuring Nash's "disappointment factor", or perhaps through periodic public opinion sampling of potential users, or through issuing all interested users a one-time use license (much like a hunting license) that could either be used privately, or through the services of a commercial outfitter. All options have been suggested and dis-cussed, and are fraught with bureaucratic headaches, if not nightmares.

A second area of needed research is that raised by Lime (1975a): "How do cur-rent and potential users define a high quality river recreation experience?" How do users relate to the values of "doing-it-on-your-own" where there is an undeniable spirit of adventure or pioneering aspect to the river outing? There is a certain im-mediacy and challenge to the "do-it-your-self" outing that results in personal sat-isfaction. On the other hand, how do users relate to the values that can be gained through participating in a commercial outing--one that gives the user a full range of experiences, from learning to row, paddle, read river currents, to identifying flora and fauna?

JUSTIFICATIONS FOR AND RESPONSIBILITIES OF COMMERCIAL OUTFITTING

The Wilderness Public Rights Fund says it is not their objective to eliminate com-mercial outfitters "...and thus abridge the rights of that portion of the public that has neither the time, inclination, or cap-ability to organize and participate in a noncommercial wilderness trip". Neverthe-less, if they win in court, I believe their position could dictate the eventual phasing out of all commercial enterprise in the wilderness (or at least, within National Parks). I, for one, accept the WPRF challenge of commercial outfitters having to be the first ones to justify their own existence.

Every outfitter I've spoken with or received a questionnaire from in recent weeks believes that commercial river outfitting is justified at least because it provides access for those people who either cannot do it themselves or who choose not to make the necessary investment in time and money to develop the proficiency and accumulate the equipment necessary to do it themselves. (This choice that the user makes suggests an axiom: the more technically difficult and logistically involving a given river outing is, the greater is the justification for commercial outfitters.) To provide access, then, is a primary justification.

One way to answer the question, "how essential are these outfitter services?" is by suggesting that the current level of commercial river outfitting would not be what it is had the public not demanded it so, indicating that some essential need for outfitter services had been filled in the market place. So, providing access in response to public demand has given rise to a certain past business level measureable (at a bare minimum) in terms of the commercial allotments established on many restricted back country rivers today. But the question remains, within a closed market system facing competing user interests and fluctuating demand, can simply responding to public demand justify commercial outfitting in the future?

Some commercial outfitters--the ones who fail to see that a totally free enterprise system is not workable in an area of such limited supply--would assert that meeting demand *is* adequate justification. Alas, they are shortsighted and assure their own ultimate demise by failing to define their future responsibilities and opportunities.

I believe that commercial outfitters are justified for another reason besides simply meeting demand for access to a certain type of recreation. Commercial outfitters can provide a range of experiences that satisfy an inner need people have to grow, to gain something from their experiences. This "gain" is very elusive and ultimately subjective. It can not be made to happen; an outfitter can only set up circumstances which foster it. This gain becomes evident in many ways: a different perspective gained from solitude or a change in activity, respite from the increasing complexities of technological society, a gain in appreciation for a body of interpretive knowledge, a gain in closeness with family and friends; a gain in appreciation of the need to conserve more wilderness. We can call these gains "educational experience"; on many commercial river outings this experience is there for the passenger to the degree he or she wants and elicits it.

QUESTIONS RAISED BY THE EDUCATIONAL JUSTIFICATION

Justifying commercial outfitting services on the basis of their providing an educational experience raises some interesting questions. (1) Could permits to use rivers be alloted on the basis of the "educational" nature of the trip? Such a concept was tried by the Bureau of Land Management on the Green River in Utah a few years ago, but was dropped after a season. Most outfitters I have spoken with feel that an educational field trip on a river is inherently more commercial than private. Adopting an educational allotment would tend to take the educational justification away from the commercial operation, when just the reverse should be encouraged. In my own experience, most biology and geology field trips on rivers are no more educational than the better run commercial outings. Commercial guides are commonly as well informed about the river resource as the instructors sent by the educational institution sponsoring the field trip. (And commonly just as much beer is consumed on an educational outing as on a commercial trip.) College credit does not insure a greater educational content.

(2) Is the quality of the educational experience derived from a commercial trip different from that derived from a private trip? A private trip is just that, a private trip. As long as the resource and participants are protected from harm, it should just be allowed to "happen". The basic educational experience on a private outing will be found in just "pulling it off" and will be subjectively different for each group and each participant. On the other hand, the regulatory agency can encourage, expect, and evaluate the educational experience encountered on a commercial river outing. The commercial participant doesn't have to worry about "pulling the trip off". Once the boat departs each

rticipant may become receptive and in-
lve himself as much in the experience as
is ready to become involved. Some pas-
ngers want to know very little; others
n't be told enough. And who's to judge
at either approach is right or wrong?
riad facts about the resource are of
ttle value unless the guide encourages
e passenger (through itinerary, words,
d example) to try to appreciate the over-
l picture--and to question man's relation
the environment.

(3) And how does the regulatory agency
sure that the educational experience is
ere for the commercial passenger who
nts it? That's a tough question that I
n't answer except to say it's going to
ve to happen at some point. The answer
ll have to begin with defining an educa-
onal criterion relevant to each operating
ea. Then it will take more money than
present to evaluate compliance with ed-
ational standards. And lastly, it will
ke more "clout" than most agencies have
present (and no small measure of courage)
enforce compliance.

CONCLUSION

All these suggestions imply more reg-
ations and raises the spectre of "Big
other". How do we face up to the nec-
sity of enough regulations to prevent
aos while at the same time preserving the freedoms and the very spontaneous quality that a wilderness river experience should have? Byron Shelby[1] of Human Ecological Research Services provides the best answer to this question that I've seen. "While some rules simply require better preparation or advocate one camp practice over another, others may become oppressive in imposing schedules or routes [or a specified educational format]. In the case of commercial river trips, such things affect passengers only to the extent that the boatmen make them apparent." The guide, then, may have to sacrifice the spontaneity of his own personal river experience for his passengers.

My contacts with commercial outfitters indicate that they fall into two groups, the pessimists and the optimists. The pessimists feel that there are already far too many regulations; realistic business projections are impossible to make and profits are bound to dwindle. The optimists, including myself, recognize that regulations are necessary and are not too worried about commercial outfitting being able to justify itself; plainly and simply, we just have too much to offer the public in the way of access and education.

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[1] *Shelby, Byron. MOTORS AND OARS IN THE GRAND CANYON; RIVER CONTACT STUDY FINAL REPORT, Pt.2. 41 p. Unpublished report submitted to National Park Service, Grand Canyon. June 1976.*

CONTRIBUTED PAPERS

SOME ECOLOGICAL CONSIDERATIONS ASSOCIATED WITH RIVER RECREATION MANAGEMENT

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ABSTRACT.--Drawing from an ecological study on the Colorado River, four river recreation management concerns are discussed: (1) river research vs. river management--their interrelationships and priorities; (2) extensive resource inventories--their role as indicators of environmental deterioration; (3) human impact--its identification and proposed mitigation; and (4) suggested guidelines for identifying unique and ecologically sensitive areas. Other environmental degradents not directly associated with human impact, but nevertheless a source of concern for river managers, such as habitat destruction by wild asses are also discussed.

River management is a new and challenging discipline. Within the last few years use of our wilderness rivers has increased explosively, creating a myriad of problems for the various State and Federal agencies entrusted with the care of these resources (Huser 1975). Many managers lack basic information about their particular river: for instance, what kinds of plants and animals occur in the river and on its beaches; what effect do river users have on wildlife; how many people can the beaches support without causing irreversible damage; how many campsites are there; and so on. Realistic management plans cannot be developed without this information. I would like to consider the development of such information as it applies to the Colorado River through Grand Canyon National Park, perhaps the ultimate in white-water travel.

Between 1967 and 1972, river running in the Grand Canyon grew from 2,099 users to 16,432, an increase of 682 percent. This alarming user-growth rate forced the National Park Service to limit the number of boaters. The commercial allotment for 1972 was set at 105,000 passenger days (pds). Of these, only 88,135 were used so for 1973 the allotment was lowered to 89,000 pds. In 1973, 86,264 pds were used, therefore the 89,000 figure has been maintained to date.

The National Park Service quickly realized that this tremendous increase in the number of river runners was damaging portions of the rivering environment. Another consideration was that the quality of the river experience was in jeopardy as a direct result of increasing numbers of users. Additionally, private users complained that permit allocations were prejudicial in favor of the commercial outfitters. These and other problems added to the complexity of determining an equitable management solution.

RESEARCH PROGRAM

In 1973 the National Park Service initiated a multidisciplinary research program designed to examine the physical, sociological, and ecological factors affecting the carrying capacity of the river environment (Aitchison 1976). From 1973 to 1976 investigators from more than a dozen research institutions par-

ipated in this project (Johnson and tin 1976).

The road from recognition of a prob- through research to development of agement alternatives and then, finally actual implementation of a management icy is long and difficult. River recre- on on the Colorado River within the nd Canyon has proven to be no exception.

User Impact

Information concerning the spatial use terns of the river runners was sought. ough a "visitor usage card" given to h trip leader, data on campsites used, ber of people in party, whether or not ood fire was built, whether or not contents of the portable toilet were ied, etc., were obtained. Surprisingly, results showed that more than 300 camp- es were used along the 280 river miles ween Lee's Ferry and Pierce Ferry. The t obvious step was to identify and cate- ize the types of human impact. Impacts problems discovered included fire, lit- ing, trampling of vegetation, and human te disposal.

Fire is integral to any natural terres- al ecosystem. However, man-caused fires generally detrimental. In riparian tems impact may range from small sand- rred fire-rings to entire stands of ch vegetation being consumed in a holo- st. In Grand Canyon, fires have been sed by careless burning of toilet paper. rt-term biological effects may include mination of actual or potential wild- e nesting sites, foraging sites, and playing sites. Large burns may kill or ce movement of certain animals and may ourage the introduction of non-native neer species.

Littering, and this includes the ctice of dumping juices out of canned d and leftover organic waste at camp- es, may increase populations of cer- n noxious insects or vertebrates. In Grand Canyon, heavily used campsites m to have correspondingly higher den- ies of harvester ants (*Pogonomyrex ifornicus)*, commonly known as red s. Because of its painful, toxic ng, this species presents a minor lth hazard to the camper. The sh fly *(Sarcophagidae)* and blow fly *lliphoridae)* populations also show this increase at "messy" campsites. These insects could become a source of fly-vectored diseases.

The increases in insect populations have also caused an increase in certain vertebrates. Lizards congregate near dirty campgrounds. Two exotic bird spe- cies, house sparrow *(Passer domesticus)* and starling *(Sturnus vulgaris)*, have been introduced in remote areas, specifically the Deer Creek and Granite Park areas, primarily through the improper disposal of garbage. Four species of mammals (skunks, *Spilogale gracilis;* ringtails, *Bassariscus astutus;* rock squirrels, *Citellus variega- tus;* and mule deer, *Odocoileus hemionus)* have increased in high-use areas, probably as a result of an increased food supply. Unfortunately these unnaturally high den- sities have caused these mammals to be in poor health, creating a potential human health hazard.

An outstanding direct impact caused by the river user has been vegetation trampling. In many areas multiple trails, all with the same ending and beginning place, are maintained simply through large numbers of people trampling the vegetation. This condition invites accelerated soil erosion and dramatically changes the flora of these areas. On the other hand, some beach areas would probably become uncamp- able if the vegetation (such as the exotic salt cedar, *Tamarix chinensis)* were not held in check through this trampling.

Human waste disposal is a concern everywhere but even more so when the num- ber of campers is high, the areas for burial of sewage are limited, and decom- poser bacteria are scant. This is the situation in the Grand Canyon. Even after a year fecal coliform bacteria were still viable in the beach sands (Knudsen *et al.* In press). Because of this and limited burial areas, it is not uncommon to un- earth a previous human waste dump when digging a hole to empty your portable toilet. A potential health hazard exists with a solution still in the future.

Of great interest are our rather sur- prising results concerning the amount of impact versus the number of users. No significant correlation was found between the number of campers and the total amount of impact. It appears that small to large

groups are capable of producing about the same amounts of impact. Perhaps Grand Canyon beaches have a very low threshold of tolerance for users. Or more probably the camping practices play a more important part in determining impact than total numbers of campers. For managers this implies that setting carrying capacity limits based simply on total users may not alleviate environment degradation; modifying visitor behavior may be the solution (Lime and Stankey 1971).

Along with delineation and quantification of the various types of human impact there is also a need to identify biologically unique or ecologically sensitive areas. The guidelines for doing this would vary somewhat for each specific river. For example, along a silt-choked desert river, clear side tributaries become an important habitat to much of the native wildlife; whereas, on a mountain river, a quiet pool may be biologically important for breeding fish. The point is, the expertise of the ecologist is needed to decide what areas in or adjacent to the river must receive top priority in terms of protecting the biotic resource.

The biologist working in Grand Canyon is greatly handicapped by a lack of previous research. Even though John Wesley Powell did his pioneering geologic investigations more than 100 years ago, the first extensive, systematic biological work did not begin until 1970, seven years after construction of Glen Canyon Dam (Wertheimer and Overturf 1975). Without extensive resource inventories there is no way to discern whether or not changes are taking place. Biological inventories of plants and animals, their types and numbers, their location and habits, and other pertinent information all aid in establishing a bank of data to be drawn upon by the field ecologist.

Impact of Glen Canyon Dam

Probably far exceeding any damage the river runner could inflict upon the Canyon have been the effects of Glen Canyon Dam. In 1963, the gates of Glen Canyon Dam were closed and the river ecosystem was altered by the hand of man as never before. Instead of a river of mud and silt, "too thick to drink and too thin to plow", a clear, cold green flow was released from the dam. Indigenous fish species were reduced in numbers because of cooler wat[er] (Suttkus 1976). Annual scouring and replacement of beaches by high volume flooding has been eliminated. An entire new, primarily exotic riparian community has developed.

For Colorado River rafters, the hydr[o]-electric dam presents mixed blessings. [On] the one hand, daily river level fluctuations now occur in response to power demands in distant cities. Sometimes these fluctuations make certain rapids unnavigable. Commonly a boat moored at "high water" is left high and dry by next morning's "low water". On the other hand controlled release of water makes trips possible during dry years when natural runoff would have been insufficient to float a boat. Also, the relatively clean clear water is welcomed for drinking and bathing.

The river manager is essentially dealing with a man-made ecosystem, a somewhat ironic situation when one remembers that the National Park Service is charged with the protection of our natural and supposedly native habitats. How does the manager confront this dilemma? He or she has two alternatives: (1) lobby for the removal of Glen Canyon Dam, that would return the Colorado River ecosystem to its native state, or (2) manage the existing river environment as if it were the native condition. At the present time, alternative 1 is not practical (however, future environmental conditions and political considerations may change this). Therefore, at this time, alternative 2 is the only choice the manager has. He or she must consider the management of the changing Colorado River ecosystem with the conservation ethic of the National Park Service as the prime guideline.

Animal Impacts

In the Grand Canyon, the presence of Glen Canyon Dam and the numbers and activities of river recreation enthusiasts are not the only problems facing the manager. Recent investigations (Carothers *et al.* In press) have demonstrated that the feral ass (*Equus asinus)*, descended from released or escaped domesticated stock of early explorers and prospectors, is causing serious damage to the river

ources and to some extent interfering h the quality of the river recreation erience. For the most part, the act of the feral ass is concentrated the western portion of the Grand yon and the damage is mediated in the m of overgrazing, trampling, soil paction and the fouling of campable ches. Many areas within the National k are suffering irreversible damage. management implication here is ar: these animals must be removed m the Park.

RESEARCH IMPLEMENTATION

Once research has been completed, agement alternatives can be proposed. etimes these recommendations conflict h current management policy; sometimes y require the manager to reexamine his ls.

River research can *only* answer *how* acts are being made and then suggest ropriate mitigation. River managers, the other hand, in addition to con- ering ecological factors, must also sider certain political and economic straints before deciding what becomes "acceptable" level of impact. This, course, is a complex problem and not essarily based on resource impact. orities must be examined. What becomes eptable impact in the middle of a wded campground may be totally unnac- table in a primitive setting. Perhaps artial solution lies in defining the ource (Leonard 1976). For example, if area is defined as Wilderness and to managed as such, then legal constraints ve as guidelines for the manager.

Unfortunately, implementation of the management policy may be the weakest link in the chain, especially if the new policy differs greatly from previously enforced regulations. The river user stubbornly refuses to accept new regulations, preferring to stick to "old and accepted ways". Some openly defy managers; others are simply ignorant of the new rules. Education of the river runner may be one solution, because regulations are usually easier to accept when the rationale behind them is understood.

Specific management objectives, purposes, and regulations must be devised for each river system. A generalized plan does not work because each river is unique. What may be applicable to a slow-moving desert river may not be appropriate or practical on a rampant mountain torrent.

SUMMARY

We have seen then, that the ecologist's role in river management is an important one. He or she must inventory this biotic resource, identify the types of river running and related impacts on the biota, and recommend appropriate alternatives to the river manager. Additionally, the ecologist can suggest guidelines for identifying unique and sensitive areas to help in preserving the naturalness and wilderness aspect of our National Parks.

Then the manager must establish and implement policies. Time is short; these management decisions must be made now, tempered with continuing ecological research. If management procrastination persists and bureaucracy red tape prevails, we may lose our wilderness rivers.

COLORADO RIVER CAMPSITE INVENTORY

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Colorado River Research Series, Contribution No. 19)

ABSTRACT.--Shoreline beaches along the Colorado River in the Grand Canyon are regularly used by river-running parties as overnight campsites. The availability of campsites in river sections where they are scarce, small, or both, limits the number and size of river-running parties that can be permitted without risking unacceptable environmental degradation. Because this upper limit depends on the number, size, and distribution along the river of campsites, a comprehensive inventory of usable campsites was needed. We made such an inventory of campsite locations and capacities and found 345 campsites usable for overnight camping by river-running parties.

With the influx of river-running recreationists into undeveloped sections of rivers, the wilderness aspects of these environments may be endangered by overuse. The greatest impact of river-running is in the use of shoreline beaches for overnight camping. Beaches on many sections of western rivers are not continuous, as on a seashore, but are discrete entities and limited in number. Visitor carrying capacity of a river section for river-running is a function of the number of beaches for campsite use, their locations, and their individual capacities. Therefore, the first phase of a project to assess the overall carrying capacity of the Grand Canyon river-running system was the campsite inventory described here.

The carrying capacity of any single beach is a function of the physical characteristics of the beach, the number of campers, group size, and the frequency and manner of use. By definition, the carrying capacity is the maximum number of camper days per year, or season, for which a beach can be used and not suffer unacceptable degradation under the management and maintenance procedures that are employed. The carrying capacity of a beach may be changed by changing the management or maintenance practices or by other factors, such as er- sion, encroachment by vegetation, or irre- versible degradation by overuse.

Campsite capacity, in contrast to ca- rying capacity, is the number of campers that can occupy a campsite overnight. T campsite capacity for undeveloped sites, though not an absolute number, limits the mean daily carrying capacity and, therefo is one of the factors determining the carr ing capacity of the system.

River-running on the Colorado River the Grand Canyon region is managed by the Grand Canyon National Park mainly on a co cessionaire basis. Use of the River has reached a plateau of about 120,000 passenger-days per year with the limit on passenger-days per concessionaire set by the National Park Service. Nonconcession- aire trips are accommodated but are a mino portion of total use. The river-running parties use the beaches along the river fo overnight camping. There has been no camp site development, so all support for campi must be carried by each party. Selection campsites has been primarily left to the discretion of the trip boatmen. Prior to

is inventory, neither the number of camptes and potential campsites nor their cacities were known; estimates of the number sites ranged from less than 100 to more an 200.

OBJECTIVES

The primary objective of the project s to determine the carrying capacity for ver-running parties on 240 miles of the lorado River from Lees Ferry, Arizona, to paration Canyon, by locating campsites and timating their capacities.

A secondary objective was to collect ta on factors that affect the carrying pacity of the river system for rivernning parties: (1) the suitability of mpsites for camping and related activities, ch as bathing, campfires, sanitation dissal, and boat mooring; (2) the status of getation on campsites, particularly its tential for encroachment into the campte; (3) the present and potential influce of wind and water erosion on beaches; d (4) the effects of camping activities the campsites.

A tertiary objective was to construct a seline data bank, including aerial photoaphy augmented by ground truth data.

METHODS

Preinventory Preparation

Photointerpretation was begun using U-2 gh-altitude photography, furnished by the tional Park Service, to gain an initial assment of the magnitude of the low-level otography photointerpretation task. Lowtitude aerial photography of the river, e shorelines, and beaches was obtained by e Remote Sensing Branch of the USGS (Unit States Geological Survey) at Prescott, izona.

For each mile, beginning at Lees Ferry, mile mark was made on the appropriate otograph, and the photograph was labeled r easy reference in the field. All pontial campsites that could be identified photointerpretation were annotated on e photographs.

Inventory Field Procedures

General Procedures

Three types of field evaluation were made for each visited site: campsite characteristics; vegetation ecology; and shoreline, beach, and water characteristics. Campsite evaluation included camper capacity estimation, type and stability of the footing, status of the firewood supply, shelter, use, open fire sites, and hazards. Evaluation of the vegetation was limited to that growing in and near the site and emphasized the identification of species, vegetation communities, and the assessment of selected species that can invade campsites. The shoreline and water were evaluated for landing and mooring of river craft and bathing. The beaches were evaluated for slope, erosion, and nature and bearing of the beach material. In addition to the evaluation, notation was made of specific features concerning the campsite. One to four panoramic ground photographs were taken of each campsite.

Progress was tracked continuously using the aerial photographs to make sure sites were not missed. During transit or after a cursory visit, a determination was made whether the site should be evaluated or eliminated from the inventory because of inaccessibility or inadequate camping area. In addition, for those sites to be evaluated by photointerpretation instead of by a visit, landing and mooring characteristics were annotated on the aerial photographs during transit.

Sampling of Beaches

The pretrip photointerpretation yielded more than 400 identifiable potential camping beaches. Because it was not possible to visit all of them, it was decided that beaches in the section from mile 8 to a point to be determined in transit would be visited. The point where this complete sampling would end would be determined by the ability to gain the desired data by *a posteriori* photointerpretation, the rate of progress of the fieldwork, the concentration of beaches, and the degree of proficiency the research team gained in transit.

Complete sampling was done through mile 40. Beaches in the section from mile 40 through 73 were relegated to *a posteriori*

photointerpretation primarily because they were numerous, large, and well exposed on the aerial photographs. About four beaches were visited for a sample in this section.

All potentially acceptable beaches were visited from mile 74 to mile 166. In this section beaches are scarce and small. Thus, they are likely to seriously restrict river-running carrying capacity if you consider only the number of campsites as a factor.

In the section from mile 167 through mile 240, numerous large beaches exist. About 15 beaches were visited in this section and the remainder were analyzed by photointerpretation.

Postinventory Analysis

Reconciliation of Data

All data were cross-checked and compared with the displayed ground photographs, aerial photographs, maps, and other related literature such as river runners' guides. By doing this for each campsite, it was possible to resolve most anomalies, fill in occasional missing data, appropriately name campsites, and record the verified data on a single data form. Subsequently, these encoded data were entered into a computer-accessible disk file and a computer program was prepared to print out the description of each campsite.

RESEARCH PRODUCTS

Four major types of data resulted from the inventory: (1) computer-printed written descriptions in tabular form of each campsite (fig. 1), (2) ground photography, (3) annotated aerial photography, and (4) strip maps.

The Campsite Inventory

The inventory does not include the beaches that were determined to be unsuitable for camping by river-running parties. In order to qualify as a campsite, the camper capacity above the 24,000 ft^3/s water level countour had to be 8 or more. That water level was considered to be the minimum safe high-water mark and it was reasonably well-defined by shoreline vegetation and erosion scars. The landing and mooring location had to be within 50 yards of the camping area,

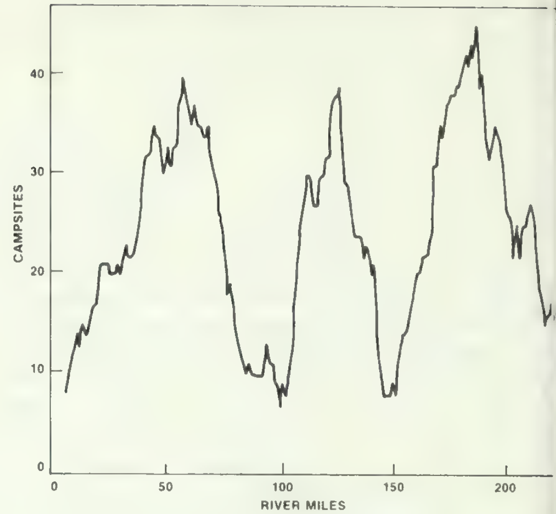

Figure 1.--*Campsites with a capacity of 2[illegible] or more in 20-mile sections of the Gr[illegible] Canyon River.*

and landing and mooring had to be possibl[illegible] for all types of river-running craft pres[illegible]ly in use. Sites that had been overgrown [illegible] vegetation or for which the campable area [illegible] blocked by a broad, dense band of shoreli[illegible] vegetation were excluded. Sites that occ[illegible]red in wash channels from tributary canyo[illegible] were also excluded.

Campsite Characteristics

Location and name.--Each campsite lo[illegible]tion is given in miles and tenths from Le[illegible] Ferry according to the 1923 USGS. The te[illegible] of a mile means the campsite occurs withi[illegible] that tenth. The L or R symbol indicates t[illegible] shoreline, left or right, respectively, o[illegible] which the campsite is located looking downriver.

Campsites that were visited in the su[illegible]vey were named predominantly for significa[illegible] local features. If no such feature exist[illegible] it was named by the mile number rounded of[illegible] to the nearest half mile.

Type.--Three types of campsites are d[illegible]fined: sand, ledge, and sand-ledge.

Capacity.--The campsite capacity is given as the approximate maximum number of people the campsite can accommodate for an overnight stay. The numbers are reported 8, 10, 12, 15, 20, 25, 30, 35, and 40, whe[illegible] 40 means 40 or more.

Method of evaluation.--Evaluation was e by either a visit or by interpreting aerial photographs. Only the capacity ld be estimated by photointerpretation is not as reliable as that obtained by isit.

Use.--Evaluation of the degree of use based primarily on evidence of long-term an impacts such as the condition and num- of fire sites and the magnitude of vege- ion disturbance. The following categories e used: no apparent use of the site for ping, light use, moderate use, and heavy .

Stability.--Erosion by foot traffic and sequent wind erosion of such disturbed erial occurs in campsites that are located unstable sand deposits. Such erosion may degrade the area as a campsite, but it l change its character and cause it to e its natural appearance and characteris- s.

Campsite stability was rated by the fol- ing: (1) stable campsite with a flat or tly sloping surface and with a firm bear- , (2) moderately stable campsite with mod- te slopes within the general use area and ed on loose sand, and (3) unstable camp- e with steep slopes within the general use a and based on very loose sand.

Fire sites.--The evaluation of fire es employed the following categories: no e sites evident; a single, neat fire site dent; more than one neat fire site evi- t; and one or more dirty, messy fire es spread over a wide area.

Firewood.--The evaluation of firewood loyed the following classes: none present, ittle present, some present, and plentiful.

Shelter.--Shelter was classified as fol- s: None, some campers could shelter, most pers could shelter, all campers could lter, and most campers could sleep under lter.

Hazards.--All of the campsites have ards that are typical of the wilderness ironment of the Colorado River. For se campsites in which unusual hazards e present, but not so dangerous as to qualify the site for camping, the haz- s were identified.

Shoreline, Beach, and Water Characteristics

Landing and mooring.--Landing and mooring evaluations, which apply to rowing as well as motorized craft, were classified as follows: (1) good approach with no off-shore rocks or shallows exposed at low water; (2) adequate approach but requires careful planning and maneuvering for rowing craft due to currents, or mooring requires care because of sharp rocks, off-shore rocks, or shallows; and (3) poor landing approach for any craft, or dangers exist for people or crafts while moored, such as swift shoreline currents or many sharp rocks on and near shore. Potential campsites were disqualified if the landing approach was exceptionally difficult.

Water stage.--Water stage pertains to the hours from 9 p.m. to 6 a.m., the time during which a boatman must tend the moored craft to avoid grounding, etc. Water stage was classified as follows: increasing flow at night, decreasing flow at night, increasing flow to high flow followed by decreasing flow during the night, decreasing flow to low flow followed by increasing flow during the night, and variable flow pattern depending on day of the week and released volume.

Bathing.--Bathing classifications were as follows: safe for bathing with a firm, gently sloping beach, shallow water, and weak currents; adequate for bathing with a steep or soft beach face, rapid off-shore drop, or rocky beach but with only weak currents; and dangerous for bathing due to rapid off-shore drop and swift shoreline currents.

Beach.--Beach characteristics apply to the area between the campsite and low water level. Although beaches are commonly considered to be sandy deposits forming shorelines, rocky shorelines have also been included. These characteristics were composed of three parts as follows: (1) material--coarse to medium sand; fine sands or silts; and rocks composed of exposed bedrock, angular bedrock debris, or rounded river cobbles or boulders; (2) slope--gentle (less than 10^{o}), moderate (10^{o} to 20^{o}), and steep (greater than 20^{o}); and (3) bearing--firm footing and soft footing (feet sink more than 3 inches into deposit).

Erosion.--Erosional conditions were classified as rapid, indeterminate, or none.

Vegetation Characteristics

A number of species are serious invading plants because they encroach into campable areas or beaches and exclude the beach for camping. These were the only ones inventoried and are given with their inventory names: tamarisk *(Tamarix pentandra)*, arrowweed (*Pluchea sericea*), camelthorn *(Alhagi camelorum*), coyote willow *(Salix exigua)*, Russian thistle *(Salsola Kali* var. tenufolia), and foxtail brome *(Bromus rubens)*.

Invading species present.--For each of the species tabulated above that was present in or near the campsite, the corresponding name is given.

Predominant invading species.--If one or more species predominate in ground coverage over all others present, the corresponding names are given.

Invasion assessment.--The invasion assessment categories were defined as follows: the beach has been completely invaded by the species in otherwise campable areas or access to campable areas has been blocked entirely by encroaching vegetation; the species are well established on the beach and are vigorous with regeneration strongly evident, but campable areas have not yet been invaded to exclude camping, although encroachment into camping areas appears imminent; the species are well established on the beach, but exclusion of camping because of vegetation encroachment has not occurred, and the potential for this occurrence cannot be determined; the species are well established on the beach in or around the camping area and camping activity appears to control further encroachment; the species are present on the beach but are not well established and the potential for encroachment into camping areas cannot be determined; and invading species are not present or, if present, are not encroaching into campable areas and do not present any evidence for potential encroachment.

Comments

Local features of interest and river-running considerations, such as the proximity of major rapids and accessibility by hikers, are given.

Cross-Reference Data

Ground photography.--One to four ground photographs were taken of each campsite visited. A caption was made stating pertinent information.

Aerial photography and maps.--Aerial photographs taken just prior to the camps survey have been annotated showing the lo tion of inventoried campsites by the loca tion conventions used in this inventory. The reference numbers of the aerial photo graphs on which the campsite is shown are given for each campsite. Strip maps of t river have been annotated showing the mil point down the river from Lees Ferry. Th center point for every fifth aerial photo graph has been annotated on the strip map for cross-referencing aerial photographs river locations and campsite inventory da

Collection Date

The month and year of data collectio are given for each campsite. For expedie the inventory has already been updated by additional information gathered in conjun tion with a followup investigation. In co tinued updating, the collection date that refers to the last update for a campsite becomes important.

RESULTS

The inventory was conducted to determine the user carrying capacity of the system. The total number of campsites was found to be 354, of which 26 percent had capacities of 8 to 15 campers, 35 percent had capacities of 20 to 35, and 39 percent had capacities of 40 or more campers. Overall, then, smallness of campsites is not a limiting factor for use. The average numb of campsites per mile from Lees Ferry to Separation Canyon is 1.48. For campsites with capacities of 20 or more, the average is 1.09 per mile, or 21.9 per 20 miles. Rowing rafts can cover about 20 miles in a day. The average of 21.9 campsites per 20 miles suggests a deceptively large carryin capacity. It does not take into considera tion the distribution of campsites, which is extremely nonuniform (fig. 2). The ran is from less than 10 to greater than 40 pe 20-mile section. The most important featu of the distribution is that three critical stretches exist which will limit the carrying capacity. If rafts cannot travel more than 20 miles per day, the number of camps in the 20-mile section with the smallest n ber will set the use limit on the whole sy tem. The three river stretches are all ne ly the same in this regard. Besides the influence on carrying capacity, these three stretches will be the most critical for mo itoring, maintenance, and scheduling.

```
LOCATION -- R  7.9          NAME -- BADGER CREEK

                    CAMPSITE CHARACTERISTICS

TYPE -- SANDY                       CAPACITY --   40
EVAL. METHOD -- VISITED             USE -- MODERATE
STABILITY -- STABLE                 FIRE SITES -- MORE THAN ONE, NEAT
FIREWOOD -- PLENTIFUL               HAZARDS -- NONE
SHELTER -- NONE

              SHORELINE, BEACH, AND WATER CHARACTERISTICS

LANDING & MOORING -- GOOD           WATER STAGE -- DECREASING
BATHING -- ADEQUATE                 BEACH MATERIAL -- COARSE
BEACH SLOPE -- MODERATE             BEACH BEARING -- FIRM
EROSION -- RAPID

                    VEGETATIVE CHARACTERISTICS

INVADING SPECIES PRESENT -- RUSSIAN THISTLE, COYOTE WILLOW,
          ARROWWEED, TAMARISK
PREDOMINANT INVADING SPECIES -- RUSSIAN THISTLE, ARROWWEED, TAMARISK,
          COYOTE WILLOW
INVASION ASSESSMENT -- ENCROACHING

                              COMMENTS

BELOW BADGER CREEK RAPIDS

                         CROSS-REFERENCE DATA

AERIAL PHOTOGRAPHS -- 0020,0021,0022
GROUND PHOTOGRAPHS -- UPPER, LOWER
MAP NO. 1 OF 9


DATA COLLECTED -- 07/73
```

Figure 2.--*Extended computer-printed form for campsite at Badger Creek.*

Of the visited sites, 9 percent had ap-
ntly not been used for camping, 75 per-
had been used lightly to moderately,
16 percent had been heavily used. Open
sites were not evident on 18 percent of
campsites; 63 percent had only a single,
fire site; and 19 percent had two or
fire sites or had messy, dispersed fire
s.

Campsites are typically exposed with 84
ent having little or no shelter. Shel-
where it existed, was usually under
risk and this was the most frequently
untered species; 84 percent of the camp-
s had it. Tamarisk was also the predom-
t invading species on 43 percent of the
sites. Considering all invading species,
8 percent of the campsites, complete en-
chment by vegetation appeared imminent;
eas on 10 percent of the campsites human
ct appeared to be controlling the en-
chment. On 41 percent of the campsites,
e was no threat of encroachment by
tation.

Uses for the Inventory

The inventory can serve as the basis for managing the use of campsites. Additionally, it can be the basis for use-monitoring and maintenance programs. The inventory must be considered to be dynamic, and must be kept current with respect to both management data and changes in the physical resource.

The inventory can be used for selecting campsites and associated areas for research sites. The inventory and its supporting ground and aerial photographs constitute a baseline for a number of features on which temporal comparisons may be based.

Educational use of the inventory can be made in acquainting new Park personnel with the inner canyon and river-running system and in the training and workshop sessions for river-runners, boatmen, etc. The ground and aerial photographs can be particularly valuable for this purpose.

NEW INITIATIVES IN HERITAGE PRESERVATION: THE AGREEMENTS FOR RECREATION AND CONSERVATION PROGRAM OF PARKS CANADA

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ABSTRACT.--To ensure the preservation of a broad range of human and natural heritage resources and to meet the changing leisure time needs of Canadians, Parks Canada has created a new Program--Agreements for Recreation and Conservation (ARC). In full cooperation with federal, provincial, and other agencies, the ARC Program will jointly identify, plan, preserve, develop, and manage historic waterways, historic land trails, wild rivers, and heritage areas.

We have seen in the last decade in Canada an unprecendented growth in visitation to all types of parks. For example, the Federal National Parks and Historic Parks and Sites saw in 1966-67 over 13,000,000 visitors. In 1975-76 this figure had increased to over 20,000,000. During this time, all levels of government actively have pursued the establishment of new parks and sites to ensure the preservation of human and natural heritage resources and to relieve the increasing pressure on existing park systems. The National Parks system alone has grown to nearly 13,000,000 hectares from 7,500,000 hectares in 1966.

We have also seen significant changes in the leisure time activities of Canadians--wilderness canoeing and hiking, cycling and cross-country skiing have become pastimes for many. And never before has there been such an awareness of the past and such a movement to preserve it.

The creation of further traditional natural parks and historic sites is only part of the solution to ensuring the preservation of our heritage and to providing for new leisure time activities. New initiatives in heritage preservation and a broader range of recreational opportunities are required.

To that end, Parks Canada announced 1972 the creation of the Agreements for reation and Conservation (ARC) Program. is the aim of the ARC Program to ensure preservation and presentation of routes areas that contain nationally significan natural and human heritage resources. Im- plementation of the mandate is accomplis through cooperation with federal, provin and other agencies in the identification of land and water routes and heritage are and through agreements on the planning, development, preservation, and management of the agreement area's resources.

PROGRAM ELEMENTS--HERITAGE ROUTES AND AR

Heritage Routes

Three types of routes have been included in this category--historic waterwa historic trails, and wild rivers.

Historic Waterways

When looking at the history of Canad we realize that our vast systems of water routes were vital in the development of th country. Many have been used successivel by native peoples, explorers, coureurs-de- bois, and more recently by merchants as

ansportation routes. Some of these routes ich as the eight historic canals trans- erred to the ARC Program, have been by- ıssed by faster transportation methods. ertain significant historic waterways will w be reoriented to provide insights into ınada's past and to offer a variety of ıter-oriented recreational activities 'ig. 1).

istoric Land Routes

Similar in role to the historic water- ıys, many inland routes were trails of the ıtive peoples and fur traders and later ecame the settlement roads of the 19th entury. They too will be developed to rovide Canadians with a greater under- tanding of their history. They also offer xcellent opportunities for activities such s hiking, cycling, or horse riding.

In certain cases, routes will be developed which are not historic in themselves, but will serve as links to significant heritage resources.

Wild Rivers

Canada's rivers represent not only the human heritage of the Canadian people but also their natural heritage. Some, such as the Nahanni River, provide a dramatic illustration of a particular natural region of Canada. Rivers flowing through barrenlands, prairies, mountains, plateaux, and the Precambrian shield represent distinct types and figure in the interpretation of particular physiographic regions.

To evaluate a selection of Canadian rivers for possible development as wild

Figure 1.--*Following in the tradition of the coureur-de-bois, French River, Ontario (Credit: Dolan).*

river parks, Parks Canada has undertaken a technical inventory of some 65 rivers (fig. 2).

Heritage Areas

Heritage areas are unique or representative rural or urban landscapes which reflect Canada's human heritage. Ensuring their preservation involves the conservation of groups of buildings, structures, and cultural landscapes.

The Process of Establishing a Heritage Route or Area

The establishment of a heritage route or area is at all times a joint process with the participating governments and agencies. At several stages in this process, the participants have the opportunity to evaluate their involvement, to ensure that their objectives are met, and to decide whether or not to proceed to a further stage of commitment in the process.

To initiate the study of a proposal, an exchange of ministerial correspondence is sufficient, committing participants to shared costs and manpower. This feasibility study identifies and assesses the heritage resources and themes, as well as complementary government programs, constraints, and opportunities for development of a heritage route or area.

Upon a positive evaluation of the results and recommendations of this study on the part of the participating governments and agencies, a concept plan is jointly prepared.

The concept plan further analyzes the resources and proposes development and management concepts with cost estimates of the route or area, and suggests a division of responsibilities.

Upon acceptance of the concept plan, a formal agreement between the participants can be concluded. This formal agreement sets out the purpose and objectives for the heritage route or area, management structures and roles, administrative and financial arrangements, implementation procedures, individual developments, costs and time frame for development.

The management structure consists of an Agreement Board, representing participating agencies. It has authority to mak decisions required for orderly developmen of the heritage route or area. A small secretariat is attached to the Agreement Board.

The primary mechanism for public participation is an Advisory Committee compo of knowledgeable individuals representing an agreement area. The Advisory Committee ensures that the information enabling the public to enter into the process is made available in the appropriate style, quantity, and form. It advises the Agreement Board of public concerns and opinions related to development proposals and provides feed-back to the public.

Implementation of specific developments can proceed immediately following the signing of an agreement if resources are endangered, or if sufficient planning has already taken place. However, an overall master plan will be prepared for the heritage route or area by a joint planning team representing the participants to the agreement.

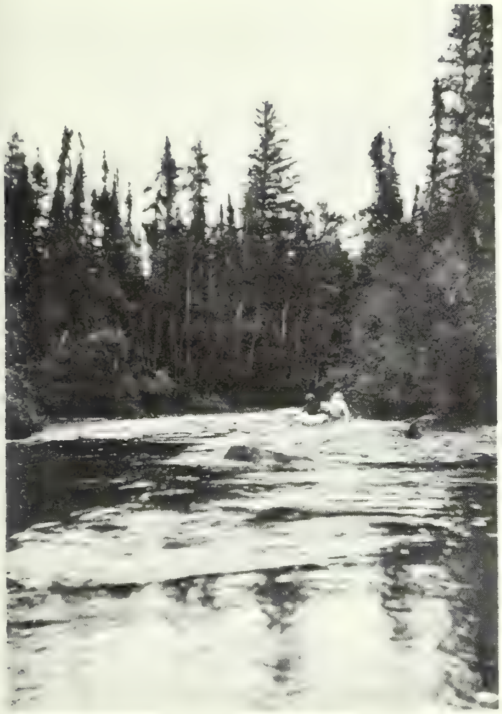
Progress to Date of the ARC Program

This joint approach to heritage preservation is a new one in Canada. Although the advantages of such an approach may have been obvious to its originators at Parks Canada, it is one which can only be successful with the full support of other government agencies, in particular the Provinces.

The reaction of the Provinces to the ARC Program has been favorable in general. Since its creation two agreements have been signed. A Federal-Provincial Agreement between Parks Canada and Ontario was signed in 1975 to develop the 425-mile historic canal-waterway running from Georgian Bay to Ottawa (fig. 3). Similarly, an agreement between Saskatchewan and four federal departments including Parks Canada has been signed to conserve and interpret the historical and natural resources of the Qu'Appelle Valley and to provide complementary recreational activities.

Joint Federal-Provincial studies are now underway on the Avalon Peninsula in Newfoundland, the Shubenacadie Canal-Chignecto Peninsula of Nova Scotia, the historic Red River in Manitoba, and

Alexander Mackenzie's route to the Pacific in British Columbia. We are optimistic that these studies will eventually lead to formal agreements with the Provinces to be developed as heritage routes and areas.



gure 2.--*Student survey party on wild river survey by Parks Canada (Credit: P. Juurand).*

Figure 3.--*One of 95 locks on the unique 425-mile Rideau-Trent-Severn Waterway (Credit: A. Current).*

VISITOR EMPLOYED PHOTOGRAPHY: A TOOL FOR INTERPRETIVE PLANNING ON RIVER ENVIRONMENTS

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ABSTRACT.--The methodology of "visitor employed photography" is explained as a device to inventory public perception of natural environments. A current VEP study on the Huron River in Michigan is summarized and the use of VEP findings in the development of interpretive services and programs for river environments is discussed.

Recreation resource managers often face the quandry of how to involve the public in the management process. Further, more and more managers are beginning to ask themselves whether their perceptions of resource quality are in concert or in conflict with those of the general public. Finally, the interpretation of the resource to the visitor public has garnered much interest and attention in recent years. A recently developed methodology, termed "visitor employed photography" (VEP), can provide valuable assistance in each of the above three areas.

THE METHOD

Visitor employed photography involves the dispensing of simple instamatic cameras to recreationists at the start of their trips. The instructions are basic: "Please photograph anything you wish during your experience today". The recreationist is also asked to write a few words of explanation on a tally sheet immediately after taking each photo. At the end of the recreation experience, the camera is reclaimed and the visitor is asked to complete a brief questionnaire. VEP is a method particularly suited to linear--or corridor--recreation environments such as trails, roads, and rivers.

Four VEP studies have been conducted since 1971, three in Michigan and one in Colorado. Of these, three involved trail hikers (Cherem 1972, Cherem and Driver 1976) and one involved river canoeists. The river study is reviewed later in this paper. The publications *Kodakery* (1974) and *Human Behavior* (1976) carried popular summaries of the VEP studies to date.

THE "UNIVERSAL PHOTOGRAPH" CONCEPT

In each of the VEP studies, a number of distinct "consensus" photographs emerged; certain identical scenes along the environments in question were photographed over and over by recreationists of different backgrounds, on different days, and in different weather conditions. The consensus photos were labeled "universal photographs" (UP) and, by definition, were photographed by from 10 to 51 percent of all recreationists passing a particular scene (figs. 1 and 2).

The 10 percent figure is arbitrary; consensus photographs of certain scenes also occurred in frequencies of less than 10 percent. They were termed "transitional photos" and represent an intermediate measure of public consensus on certain scenes. A third type of public-taken photo, the "thematic

gure 1.--*"Marsh scene" was the top UP of a Michigan VEP study. Fifty-one percent of all trail hikers photographed it.*

igure 2.--*This cabin UP was photographed by 29 percent of the hikers on a trail in Colorado.*

photograph", rounds out the story. Thematic photos are not tied to a specific scene or location but rather are of generic topics such as flowers, trails, and wildlife.

At first, it was apparent merely that UPs represented agreement of public interest in certain scenes. The universality concept gained more strength, however, when it was statistically determined that all demographic categories of visitors took the same percentage of UPs in their total mix of photos (Cherem and Driver 1976). In other words, the probability that a visitor would take an UP seemed related to the "perceptual excitement" inherent in a scene itself rather than to the background of the visitor.

The "Perceptually Exciting Node" Concept

It became increasingly apparent that certain spots along the studied environments were being experienced and perceived in common by large numbers of people. Further, the percentage scores (10 to 51 percent) indicated that certain of the spots were perceived more in common than others.

The explanation for the occurrence of these universally photographed spots lay in the tally sheets that the visitors filled out. The more sensory and landscape diversity there was at any one spot, the more likely it was to be photographed. For example, an area that contained a bed of yellow wildflowers, a dead snag, and an abundance of birdlife was more likely to be photographed than an area with a dead snag alone.

Human perceptual excitement is heightened when a number of sensory and landscape contrasts occur simultaneously (Cherem and Driver 1976). We have termed those spots that "excite" 10 percent or more of the passers-by into the behavioral response of snapping a photograph as "perceptually exciting nodes" (PEN).

The Concept of a "Perceptual Excitement Profile" (PEP)

When all the PENs along a particular environment are expressed as sequentially ordered photographs, we have what may be termed a "perceptual excitement profile" (PEP) of the environment. In short, we have a composite "public-eye-view" of the recreation resource involved.

This graphic representation can be transposed onto a base map to represent the relative intensity of public perceptual excitement along the recreational resource. Such a map may prove to be as valuable a recreation planning tool as a cover-type or soils map. The concept of a PEP must be refined a bit, however, before this can happen.

The PEN, and thereby the perceptual excitement profile, is still lacking the dimension of positive or negative value. We may be excited in a negative as well as a positive manner by contrasts in the recreational landscape. A VEP study conducted recently on the Huron River in Michigan explored the issue of positive vs. negative perceptual excitement.

VEP ON THE HURON RIVER

In June of 1976, a VEP study conducted on Michigan's Huron River investigated both the positive and negative aspects of a river's perceptual excitement. With support from the USDA Forest Service and in cooperation with the Huron-Clinton Metropolitan Authority, the study was conducted on the 4-mile stretch of river between Dexter-Huron Metropark and Delhi Metropark near Ann Arbor. This was the first attempt at utilizing VEP on rivers, so several unique problems arose that required special consideration.

Considerations Unique to Rivers

Canoe travel on a river involves some restrictions: travel is fairly rapid and in one direction, movement in the canoe is restricted, and there is the constant threat of dunking both subject and equipment. All this makes taking photographs and filling out a tally sheet awkward. These potential problems were minimized by making the VEP procedure as simple and convenient as possible.

Cameras were issued where access was easy even for inexperienced canoeists. It was necessary, however, to ask subjects to come to the researcher, who hailed them from a designated spot on the riverbank. This was the only major modification made in the VEP method for use on rivers. Participation was voluntary of course and the effectiveness of this method of contacting canoeists is reflected in a refusal rate of 37 percent.

For visitor convenience, to reduce the possibility of dunking, and to aid the research assistant in subject identification, camer were provided with a neck strap of inch-wi bright red ribbon. Tally sheets were plac on clipboards and secured with an elastic band. Moreover, the research assistant's downstream location was marked with colore flagging tape and the subjects were given opportunity to complete the post-trip ques naire without leaving their canoes.

Study Method

Cameras were handed out at 5-minute intervals throughout the day. One hundred and seventy-two canoeists were given camer and tally sheets at Dexter-Huron Metropark Half were asked to photograph anything the considered appealing or positive and the other half were asked to photograph anythi they considered unappealing or negative, as they canoed the same 4-mile stretch of the Huron River. All participants returne their cameras and tally sheets and complet questionnaires at Delhi Metropark.

Preliminary Findings

Although data analysis is incomplete several preliminary findings have surfaced. The mental set (positive vs. negative) give to canoeists seems to have been very effective. Canoeists in the negative mode tend to travel the river faster and take fewer photographs than canoeists in the positive mode. In the negative mode, the mean avera trip time was 68 minutes and the mean avera number of photographs taken was 7. In the positive mode, the mean average trip time was 77 minutes and the mean average number of photographs taken was 9.

If, as mentioned earlier, a high degre of diversity or contrast is important in defining universal photographs and PENs, th one would expect those elements most highly contrasting to the natural landscape to be most photographed as negative. Indeed, suc appears to be the case. To date, 11 univer photographs, 3 positive and 8 negative, hav been identified that meet the previously established criteria. Apparently canoeists agree more on what is negative than what is positive about the Huron River and this ten to support an earlier finding by Morisawa (1972). Thus, it appears that what is "ugl or negative is easier to define than what i "beautiful" or positive.

Canoeists in the positive mode photo-
phed such things as distant river scenes,
d or fallen trees, living trees with
tinctive shapes or forms, houses nestled
ng trees along the river, rapids and fast
er, and developed recreational facilities
ng the river. The most popular scene
photographed by 22 percent (19 out of
of the canoeists in the positive mode
g. 3). The river scene depicted in this
tograph was one of the first scenes visible
canoeists after they had received a camera
tally sheet. This scene appears to re-
ct a certain excitement in anticipation
shooting the rapids visible near the
ter of the photograph. Canoeists indi-
ed they took this photograph because
pids are fun", "it's an exciting river-
pe", "action", "fast water". Moreover,
oeists reported sensations of "tranquility
ept for the sound of rushing water", the
und of white water rushing over rocks",
"inspiring roar of churning water", "saw
light glistening on the ripples", and
dig the reflective sun off the water".
s, there seem to be several elements of
trast and diversity operating at this
ation that enhance its positive universal
eal to canoeists.

Canoeists in the negative condition
tographed metal pipes in and along the
er, powerlines, bridges over the river,
crete bridge abutments, graffitti on
dges, developed recreational facilities

ure 3.--*The top UP in the positive mode, this scene was snapped by 22 percent of the Huron River canoeists sampled.*

along the river, fallen trees in and along the river, and industrial sites. The most unappealing scene, a water tower and factory (fig. 4), was photographed by 28 percent (23 out of 82) of the canoeists in the negative mode. Canoeists indicated they photographed this scene because the water tower "looked out of place", "was the funniest looking tree I ever saw", "wrecked the view", and "it is distracting of the natural beauty and peace of nature". "Construction noise and fumes", "factory hum", "train horn", "stinks", and "buzzing noise" were reported as being typical sensations experienced by canoeists at this location on the river.

Figure 4.--*The highest negative concensus photograph, this water tower UP was taken by 28 percent of Huron River canoeists.*

In addition to those scenes photographed only by canoeists in the positive or negative mode, some scenes were photographed by canoeists in *both* modes. One scene was photographed by almost 12 percent (10 out of 86) of the canoeists in the positive mode as well as by 17 percent (14 out of 82) of the canoeists in the negative mode (fig. 5). Canoeists in the positive mode photographed this scene because it was "interesting", "different", "nice scenery", an "interesting

Figure 5.--*This photo bears the distinction of being the only UP to be perceived in both the positive and negative modes. The bridge scene was considered positive by 12 percent and negative by 17 percent of the canoeists.*

shot", and "picturesque". Canoeists in the negative mode felt this scene was "ugly", "distracting", "detracts from natural scenery", "unsightly", "noisy", and "clutters nature". The primary sensation experienced by canoeists in the positive mode was the "sound of water splashing". In the negative mode, the sensations experienced were "loud motor" and "cars nearby". Thus, it appears that one's perception of this scene depends on his orientation. If one perceives the elements of the scene as being basically natural, the scene tends to connote something positive; if he perceives the elements of the scene as being more man-made or man-associated, the scene takes on a negative connotation.

To investigate the effects of seasonal variation on the positive UP's isolated in the main summer study, a brief autumn pilot study consisting of ten samples was conducted during October 1976. The negative condition was not used in the autumn pilot study because it was felt that autumn would have a positive rather than negative influence on visitor perception.

The findings of the autumn pilot study support those of the main summer study. All of the positive UP's isolated in the main summer study appeared. Moreover, an additional UP was isolated in the autumn pilot study: nine canoeists photographed the same brilliantly colored maple tree along the river's edge. Furthermore, of the nir canoeists who took this picture, five list it as one of their top three preferred photographs on the tally sheet.

It is of interest that certain of the landscape scenes photographed in both the main summer and autumn pilot studies prese themselves for only a brief moment. This makes the presence of universal photograph even more remarkable. The fact that the general public has consensus perceptions of fleeting landscape scenes has important implications for application of the VEP technique by resource managers, and we shall now turn our attention to some of these applications.

General Applications to River Recreation Management

We stated earlier that the PEPs produ from VEP studies could be used as another type of base map to aid recreation plannin. In general, management strategies would probably aim to maximize the positive and minimize the negative PENs along a river. For example, a particular PEN could be strengthened or intensified by the introduction of more elements of landscape diversity at that spot. What is more, it should be possible to create a PEN along an otherwise neutral or monotonous stretch of river. The introduction of a vista by judicious riverbank clearing and the introduction of swift water through naturalistic wing dams would be two examples.

Visitor employed photography may also promote the most efficient use of budget and manpower. The generation of a PEP for a particular river can help in establishing and isolating priorities not only for devel ment but also for maintenance of that recreation resource. A knowledge of what the public perceives as positive and negative could greatly improve the planning process by allowing more complete evaluation of *all* the impacts of a proposed action. For exam the establishment of positive and negative perceptual excitement data would seem to be of value in preparing environmental impact statements.

PECIFIC APPLICATIONS TO INTERPRETIVE PLANNING

The Process of Interpretation

While there are minor variations in efining and modeling the interpretation rocess (Alderson and Low 1976, Brown 1971, herem 1975, Sharpe 1976), most conceptions f interpretation are built upon three major mponents: resource, interpretive media, d visitor.

Peart and Woods (1975) developed a implified version of the interpretive anning process based upon a communications odel. They conceptualize the interpretive anning process in terms of the basic uestions: (1) What (the resource); (2) Who he visitor); and (3) How, when, where (the terpretive media). In addition, their odel contains a basic and prerequisite why" (objectives) component and a final so what" (evaluation) component. Visitor mployed photography can be helpful in all ive components of the model.

The Objectives (Why)

Putney and Wagar (1973) state that xplicit objectives at the policy level ill not only define program direction and riorities but will also facilitate public nvolvement and review in setting such irection and priorities". It is in this apacity of obtaining public involvement n setting interpretive program directions d priorities that VEP can be of great use. ilden (1967) emphasizes that interpretation ust relate to the personality or experience f the visitor. What better way to relate o the visitor than to involve him in the anning process? The documentation of the otential high points of the river visitor's xperience through VEP would seem a tremendous tep in this direction.

e Resource and the Visitor (What and Who)

There is a physical reality and a perceived reality; there is a physical resource d a perceived resource.

At the purely physical level, we can nventory biota, map the topography, and ocument historical facts. Through ecological sampling, aerial photos, and tape recordings we can document the "what", that s, the stories and themes that the area as to offer.

Measuring the "visitor" component of the interpretive planning model can be far more complex, however. At the "perceived" level of the visitor's experience, resource and visitor become inextricably tied (Field and Wagar 1973). "We look, but do we see?" as the adage goes. What part of what we look at do we see? What part of what we listen to do we hear? What part registers? In other words, what part of the physical resource do we perceive? The interpretive planner needs to know what the visitor is perceiving in the resource before he can direct the visitor's attention toward or away from those aspects, sites, or themes. Visitor employed photography offers a measure of the perceived resource.

VEP gives the interpretive planner an indicator of the current level, composition, and focus of visitor perception of the resource. It yields an imageable profile of the perceived interpretive resource. As an example, let us take a recreational river for which an interpretive program has been earmarked but not yet planned. A VEP study run on such a river can: (1) help designate those sites (PENs) currently perceived as negative or positive, and (2) help isolate interpretive stories or themes through analyses of the thematic photos taken by the visitors. (For a more detailed examination of interpreting a river environment, see Anne Harrison's paper in this proceedings.)

If a particular PEN is viewed as negative, it can be dealt with in several ways. If it is easy to correct the situation (e.g., as unsightly sewer pipe), this can be done. If it is not possible to remove the negatively perceived feature (as the water tower in figure 4), then an interpretive message can be structured to minimize the feature's negative aspects (an intrusion on the riverscape) and maximize its positive features (a point in the hydrologic cycle). In other words, use the immovable negative PEN as a potential interpretive resource.

If the negative PEN is a naturally occurring phenomenon that is currently perceived in a negative fashion (e.g., a duckweed-covered eddy), then interpretation can be applied to reverse this inaccurate perception of river ecology. Indeed, Solomon and Hansen (1972) found that more canoeists perceived eroding streambanks on the Pine River positively as "dramatic cliffs" than perceived them negatively as disturbed areas.

An interpretive message could go a long way toward correcting this ecologically inaccurate perception.

If a particular PEN is perceived as positive (fig. 3), the interpretive planner can utilize this information to good advantage. The perceptual excitement and physical activity at that spot may be so intense (e.g., rapids) that the PEN should not be interpreted through onsite but rather through offsite interpretive media; or it might be decided that a particular PEN should not be interpreted at all. Perhaps the visitor should be left to experience the immediate excitement of the site for himself. With such a PEN, interpretive messages (on- or offsite) might only get in the way. Interpretive media should augment, but never compete with, the resource itself. Further, it should be understood that the PEN is a basis for reaction only. It might be decided that interpretation should occur at intervals between PENs, or "internodes", rather than at the PENs themselves, particularly if current visitor perception is totally missing a potential interpretive resource.

Thematic photographs can often suggest interpretive themes never perceived by the planner. The appearance of painted and soft-shell turtles as a heavily photographed summer item on the Huron River indicates their great interpretive potential. In addition to turtles, a wealth of photographs and comments dealing with ducks, geese, herons, and other waterfowl suggest that interpretive programs with a waterfowl theme would have high appeal and would be well received by Huron River canoeists.

As a corollary finding, the fact that most canoeists in the autumn pilot study photographed the same brightly colored maple tree as well as autumn foliage in general suggests that certain landscape elements that are perceived as more or less ordinary for most of the year may take on added significance during certain seasons. Additional VEP studies conducted at various seasons throughout the year could help to isolate and identify these seasonal variations.

The Interpretive Media (How, When, Where)

Once the visitor-perceived interpretive resource of the river has been documented, appropriate interpretive media can be selected and developed. Such a selection must take into account not only the PEP of the river but also: (1) the capabilities and potent[ial] of the physical resource; (2) the numbers, demography, and psychological characterist[ics] of the present and projected visitors; (3) interpretive program mandates and objectiv[es] as well as (4) budgetary, staffing, and logistical realities.

Sharpe (1976) presents an excellent system for categorizing interpretive media. Utilizing his classification scheme, we wi[ll] give examples of how VEP might be useful in each potential service area. Certain of the services are more appropriate to interpretation of river environments than are others.

Personal Services

Information Services.--Information dispensed at information desks or entrance stations or put-in points for river travel can alert the visitor to the positive PENs as areas deemed exciting and leave other PENs to be discovered by the visitors themselves. Further, information leaflets or river maps could use PENs as emphasized reference points to strengthen the visitor's sense of orientation, hence his feeling of comfortability with the river experience.

Conducted Activities.--On conducted shoreline boat trips, or float trips, a good deal of interpretation might occur at the more neutral internodes, leaving the visitor to experience the positive PENs, particularly where a PEN coincides with an area that demanded high physical involvement such as a rapids. If the "interpretor" (spelled with an "or" to distinguish him/her from the foreign translater) does stop to talk at the positive PENs, he must be sure that his words augment and do not compete with, the milieu. If the interpretor wishes to stop at a negative PEN, he may interpret why it is there (e.g., a water tower), hence using the site as an interpretive resource.

Talks to Groups.--Not only should talks (particularly those aided with slides) addre[ss] some PENs as reference points, but they can also address thematic photos and themes not perceived, possibly emphasizing the latter, thus developing the visitor's perception of the resource at a finer level. Further, it might be possible to break the interpretive talks into imageable sections based upon the occurrences of PENs.

Living Interpretation.--While it would first seem apparent that old mill sites, lding ruins, and historical artifacts ng rivers would very likely be PENs themves, the greatest potential for living erpretation may exist along the more ceptually neutral internodes. History difficult to visualize and living intertation demonstrations might occur best inst a neutral backdrop where the site not competing for attention. Such locans might be ideal for "ephemeral living erpretation". Imagine seeing an Indian ampment of the 1830's in a small clearing ng the river where you had not expected see it. Imagine a fur trapper stepping of the shoreline foliage in full regalia asking if you've any news of the Indian ising. Moments such as these need not be d to a specific location or time and they ld enhance a visitor's experience tremensly. To carry the living interpretation step further, PENs could even be created ng original internodes, particularly along se internodes where it is documented that tain events took place.

personal Services

Audio Devices.--In general, interpretiveio stations would seem out of place on river. These devices could be utilized good advantage at a wayside exhibit or erpretive center, however. It might be sible to orient the river traveler to auditory milieu (e.g., cottonwood leaves ttering just before a rapids) of certain s that he will experience on the river p. Conversely, the opportunity to hear ost-trip recording of audibly distinctive s might reinforce reminiscence and recall the river experience for the visitor.

Printed Material.--The positive PENs, n expressed pictorially in a publication, not only an excellent orientation device are invaluable in aiding the reader to ture in his mind the visual totality of river and the experiences it has to offer. h this "map of alternatives", the visitor ld select those sites, experiences, and reby river stretches, he wished to explore those he did not wish to explore because interests or physical limitations.

In relation to brief interpretive signs, may be possible to include verbal markers g., rapids view) on the more heavily used reational rivers to alert river travelers to a high excitement area well worth watching for. (It might even be preferable to use nonverbal markers or symbols to alert the visitor to upcoming experiences.)

Self-Guided Services.--Here again, the PENs can be reference points to help the visitor orient himself. An even greater possibility exists in the establishment of a "landmark" self-guided leaflet, encouraging the river traveler to watch for the PENs. The leaflet would contain a short, easily read interpretive message for each PEN landmark to be "digested" at or after the PEN.

Exhibits.--Particularly in a post-trip situation, the photographic recurrence in exhibits of areas deemed exciting could reinforce the memory of the trip and give the visitor a greater and more coherent sense of closure. The comments "we saw that" or "we were there" would probably ensue.

Visitor Centers.--If a visitor center were placed at a documented PEN, the planner would have to be careful that the center augmented rather than detracted from the site. The placement of a visitor center at an internode might also be a possibility. Not only might this serve as a physical rest spot between PENs but also such a center could be a point of overlap between auto access and river access, and thereby a point of articulation between, the land-oriented and river-oriented segments of the interpretive program. Indeed, the placement of a visitor center at an internode would likely have the same effect as opening a vista along a monotonous stretch of river. Site reinforcement focuses perception and attention at that site, as has often been the case in outdoor recreation settings (Tocher and Hunt 1964).

Interpretive Program Evaluation (The "So What")

Visitor employed photography can be used to help evaluate both proposed and existing interpretive programs and facilities focused upon river environments.

Once the PEP for a river has been established, it can be remeasured at periodic intervals to determine and isolate changes in the profile. Changes in the PEP for a particular stretch of river will most likely be attributable either to changes in the riverscape itself (e.g., a forest fire) or, more likely, to the effects of recreation

management along the river (e.g., the establishment of a new riverside campground or picnic area) or to the effects of a river-oriented interpretive program. Segments of such a program may have sharpened visitor perception of subtleties at the internodes (e.g., unusual plantlife) through, for example, a pretrip slide program. With properly designed questions on the tally sheet and followup questionnaire, it should be possible to determine why the river PEP has changed, thus enabling one to verify, support, or reject the effectiveness of an instituted interpretive program or facility.

The establishment of a PEP for a river with an existing recreational management or interpretive program can also be useful. Such a PEP becomes a view of public perception at that point in time. An additional VEP study conducted later, particularly after the establishment of certain interpretive facilities, can indicate or measure the change in public perception brought about by the introduction of that interpretive facility. In other words, did the visito see what you, the interpretor, wanted the to see along the river? If not, did they see something you missed altogether?

SUMMARY

Visitor employed photography is a new concept. Time and effort will refine the method and its application, not only for u along river environments but also for other linear recreational environments such as trails and roads. Experience may prove certain of the applications we have proposed useful. In addition, new applicatio for VEP and the resultant perceptual excit ment profile will emerge. We are confiden that such a visitor-generated view of the resource will be a valuable tool in recrea resource management.

STANDARDS OF ENVIRONMENTAL QUALITY FOR RECREATIONAL EVALUATION OF RIVERS

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ABSTRACT.--Explores the possibility of developing evaluative criteria and standards based upon the individual and group threshold functions by which alternative sites are accepted or rejected. Explains experimental procedures used to develop the threshold functions. Presents illustrative results of pilot studies. Suggests applications and needs for further research.

When an individual selects a location or an intended recreational activity, he ses stable and describable "rules" to evalute and accept or reject alternatives. Howver, these "rules" may be implicit or covert, nd not readily explainable through intropection. Thus, special experimental techiques may be needed if the rules are to be xtracted, described, and used to develop valuative criteria and standards.

In this paper, we focus exclusively on he environmental characteristics or attriutes of recreational sites--as they influnce the decision to accept or reject a site or an activity. The hypotheses are (1) ecreational decisions and satisfactions are trongly sensitive to the environmental ttributes of alternative sites, (2) an ndividual can recognize and differentiate etween acceptable and unacceptable sites or an activity when those sites are described n terms of their environmental characteristics, 3) the boundary between acceptable and uncceptable sites for an individual can be escribed by means of a mathematical function f environmental variables, using suitable xperimental and statistical methods, (4) he boundary will be probabilistically disributed for a group of individuals, and the endency for a site to be acceptable to the roup can be described in terms of probabilities, and (5) criteria and standards of pereived recreational quality can be developed, ased on individual acceptance thresholds nd/or group acceptance probabilities.

To date only pilot studies have been completed as part of the process of developing the experimental methods. Large-scale data collection was conducted during the past summer (1976) at the Pine River in Michigan. Comparatively small samples also were collected from other locations.

To develop criteria and standards of perceived environmental quality from the recreationist's point of view, it is first necessary to define a model of the process by which people choose among alternative sites for a given recreational activity. For want of something better, we have chosen to adopt a utility theory of behavior, or what economists call the rational model of choice (Arrow 1958). This is to say that when choosing among a number of alternative sites for a given recreational activity, an individual will always choose the alternative perceived to have the greatest value or utility for him, subject to whatever constraints might influence the feasibility or availability of alternatives. We further assume that the utility perceived to be offered by an alternative can be expressed as a mathematical function of the perceived environmental attributes of that alternative, other things being equal. Let the quantity of environmental attribute i, say water quality or wildness, perceived to be present at a site be X_i, and let V be the total utility of the site contributed by its environmental characteristics. We assume that there exists some implicit utility function,

$$F[V,X_1,X_2,\ldots,X_i,\ldots,X_n]=0, \qquad \text{[Eq.1]}$$

which describes the rational choice process. If this function could be described for an individual, his site choices then could be predicted by measuring the environmental characteristics of alternative sites, calculating the value or benefit, V, and selecting the alternative with the greatest V. Environmental attributes, of course, are only part of the choice process. Therefore, we are dealing with a partial analysis of the problem. Constraints on feasibility, if any, must also be considered.

The most direct approach to the development of individual criteria for site evaluation would be to describe the utility function represented by equation [1]. Individual functions then might be combined either probabilistically or analytically into group criteria for site evaluation. However, this approach may not be feasible at this time because of the complexity of decision processes. The problem has gone far beyond the simple theory and experiments first reported by Thurstone (1931). This is understood by referring to a recent review of utility models by Farquhar (1976). Hauser and Urban (1975, 1976) and others clearly identify many of the conditions implicit in direct modeling of utility functions. Even with this understanding, many utility modeling efforts could still produce idiosyncratic utility functions that are generally not comparable between individuals because individuals differ in value concepts.

Given the complexity of the utility function problem, the difficulties encountered when direct modeling is attempted, and the limitations from which the products suffer, this would appear to be an impractical approach to the development of site evaluation criteria and standards. However, if we restrict the question to one of site adequacy, as opposed to absolute site quality, the problem is simplified and becomes manageable.

By site adequacy, we mean a measurement of the acceptability or unacceptability of a site to individuals or groups. To predict choice completely, and, thus, to evaluate sites completely, we must be able to deal with the competition among acceptable sites. However, in line with the concept of a "standard", it would seem useful to have rules for determining whether and for whom a site is adequate or acceptable for a gi[ven] recreational activity in terms of its environmental characteristics.

The utility function concept can be used as the basis for the development of such rules. In equation [1], if V is held constant at some value, say V_o, all combina[tions] of environmental variables that sati[sfy] the equation define the V_o "isoquant", i.e

$$F[V_o,X_1,X_2,\ldots,X_i,\ldots,X_n]=0. \qquad \text{[E}$$

This equation for the V_o isoquant is a mor[e] specialized and simplified relation than t[he] more general utility function of equation [1]. All sites having combinations of environme[ntal] characteristics that satisfy this equation produce perceived benefits equal to V_o, an[d] the recreationist is indifferent among the[m].

Assume that there is an isoquant for which $V_o = 0$: that is, alternatives satis[fy]ing the equation

$$F[X_1,X_2,\ldots,X_i\ldots,X_n]=0 \qquad \text{[E}$$

are neither attractive nor unattractive because the perceived utility they generate is zero. This isoquant must be a boundary between acceptable alternatives that generate $V > 0$ and unacceptable alternatives that generate $V < 0$, or disbenefits. If equatio[n] [3] can be estimated for an individual, it can be used as a criterion or standard for discriminating among acceptable and unaccep[t]able sites for that individual. This equation is much simpler than the total utility function because the utility variable, V, does not appear in it. It is essentially the mathematical "intersection" between the utility function and the plane $V = 0$. Simp[le] experimental techniques can be developed fo[r] estimating equation [3] for individuals and the concept can further be developed for groups of individuals.

For example, consider a hypothetical person who wants to go canoeing for the wee[k]end and is looking for a good place to do i[t]. For the sake of simplicity, assume that suc[h] a person is only concerned about the following: water quality and degree of developme[nt]. Depending on the nature of the individual's preferences, many combinations of water condition and development will be unacceptable. Others will be acceptable. Presumably, the[re] is a boundary or threshold between the accep[t]able combinations and the unacceptable com-

inations that can be described (fig. 1). This hreshold might be described mathematically y specifying equation [3]. If the function an be specified, it becomes a rule for udging the adequacy of alternative sites or this person. In figure 1 we have shown nonlinear boundary in order to illustrate he possibility of nonlinear substitution elations.

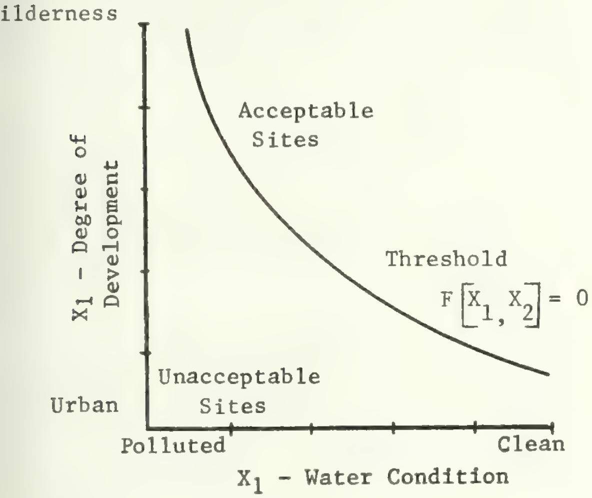

Figure 1.--*Hypothetical threshold function.*

This threshold function, $F[X_1,X_2]=0$, an be used as an evaluation standard as ollows: Given the site to be evaluated, e measure its environmental variables, X_1 nd X_2. These values are substituted into he threshold function, and the function is valuated. If the site is on the acceptable ide of the boundary, the function will have nonzero value with a positive sign. Sites n the unacceptable side will have values ess than zero. The farther a site is from he boundary, the more positive or negative ts value will be. Thus, the threshold unction can be used to discriminate between cceptable and unacceptable sites. It can lso be used to diagnose the environmental easons why the site is acceptable or unacceptable in terms of distances from the hreshold and the changes that would be reuired to bring an unacceptable site into he acceptable region.

The boundary is specified only in terms f objectively measurable environmental variables. Utility does not enter the function irectly and need not be measured. Thus, ost of the difficulties presented by utility modeling are circumvented. Comparisons can be made among individuals because of the objective nature of the variables. This reduces experimental problem to one of (1) physical description of alternative sites, (2) having the subject sort sites into acceptable and unacceptable categories, and (3) mathematical estimation of the boundary between the two sets.

Assuming that the threshold function exists for individuals, a way must be found to combine individual functions into aggregate or group rules if the method is to be useful for management purposes.

A homogeneous population, for example, is a group of similar individuals. If it is possible to identify such a group, for example white water kayakers, it would seem reasonable to expect that individuals would have similar threshold functions because of common interests, tastes, etc. We might expect the threshold functions to cluster together as illustrated in figure 2, again in terms of a two-variable example.

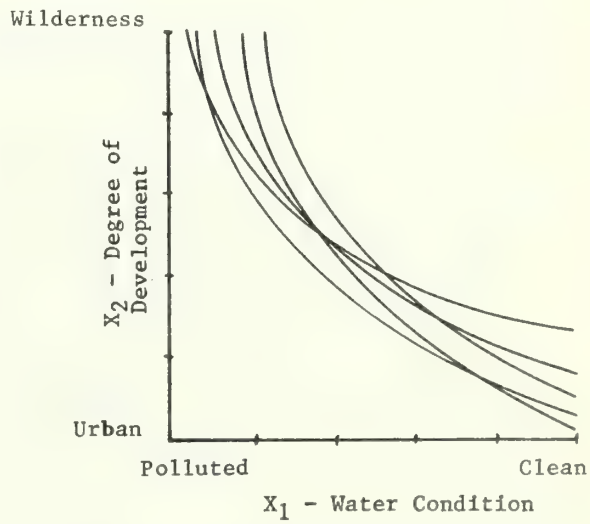

Figure 2.--*Hypothetical distribution of thresholds for a homogeneous population.*

Given such homogeneous clustering of individuals, the group could be regarded as an individual, and a single threshold function might be used to represent the group. If we have a group of recreationists that we hypothesize to be homogeneous, the hypothesis can be tested by measuring individual threshold functions and comparing

among individuals. However, this would be a very laborious process.

The tight clustering of threshold functions shown in figure 2 would not be likely for a heterogeneous group of recreationists consisting perhaps of a mixture of avid canoeists, wilderness enthusiasts, people interested in partying out-of-doors, and others simply trying to get out of the city. The dispersion of thresholds in a mixed group would probably be much greater (fig. 3).

Obviously it is desirable to stratify the users of a recreational site into homogeneous types, vis-a-vis their evaluative criteria, but it may not always be feasible. There may be many situations in which it is necessary to have aggregate criteria that represent the dispersed individual rules shown in figure 3. It might be possible to calculate an "average" threshold function for such a group; this would not be very meaningful, however, because it would not preserve the diversity that exists.

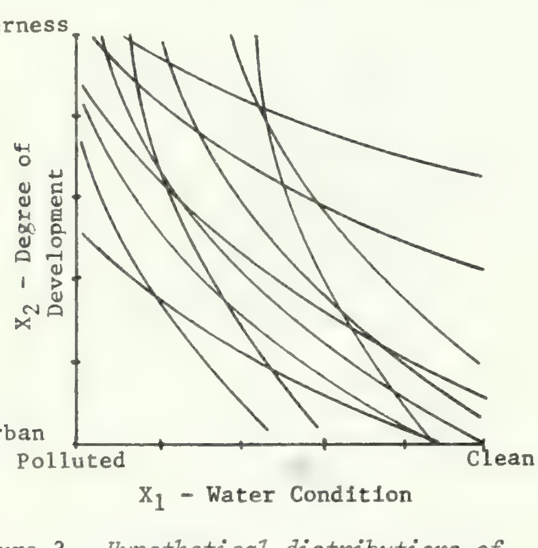

Figure 3.--*Hypothetical distributions of thresholds for a heterogeneous population.*

An alternative and more representative approach would be to describe the probability that each combination of environmental variables would be judged acceptable by a person sampled randomly from the population. These probabilities might be used to estimate "centours" or lines of equal probability (fig. 4). Given a probability function of this sort, it could be used as an aggregate evaluative criterion to measure the acceptability of a given site to the population in question. For a very heterogeneous population, the centours would be quite evenly spread over the range of alternatives, and there would be no region of unusual "steepness" or rapid change in probability with changes in the environmental variables. However, with a very homogeneous population the centours might be clustered in a region of rapid probability change (fig. 5). This region of steep gradient would serve to identify the location of a single threshold function that represents the group.

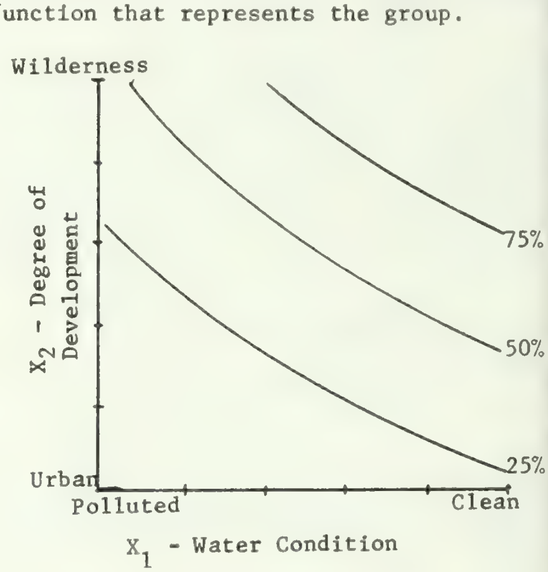

Figure 4.--*Hypothetical acceptability centours for a heterogeneous population.*

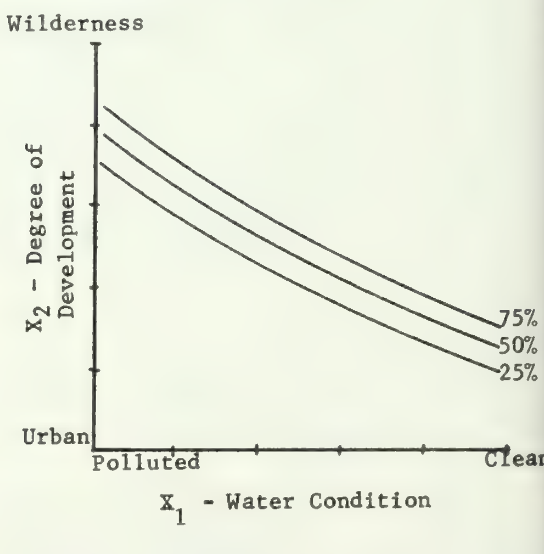

Figure 5.--*Hypothetical acceptability centours for a homogeneous population.*

EXPERIMENTAL METHODS

The technique used for measuring the vidual threshold function is similar to oaches advocated by Craik (1968) to use appraising physical environments. ctly, it can be better described as an tation of methods used for "policy extion" by Hammond (1974). In our exment, an individual is presented with nvironmental display descriptive of a r site, and asked to decide whether site is considered to be acceptable or ceptable for a specified activity. The lay used is a written description of environmental characteristics of the , although a variety of display teches might be used. The written descrip- method has often been used in consumer vior studies and seems to be valid and ible.

There are many environmental variables might be important for various recrenal purposes. To identify and define e variables is a major research underng. Rather than to attack this question, lected to experiment with the threshold ry using the following set of five ables known to be important to canoeists: water condition, (2) degree of develop-, (3) level of crowding and use, (4) h and litter, and (5) skill level reed. The tabulation shows how the scales defined; figure 6 shows how they were to generate synthetic alternatives for Pine River research. The scales and survey form were developed through a es of pilot studies, based on literature ew and the author's prior experience.

The environmental alternatives were omly generated by computer. Five scales four categories on each scale define a le space of 1,024 alternatives. To de- an individual threshold function, it d be necessary for the individual to several hundred alternatives sampled this larger set. This was done in t studies and found to be feasible, algh rather tedious. In the final exment, we presented many individuals 400) with 15 randomly generated alterves. Part of one set is illustrated igure 6. Each subject received a unique om set, and was asked to sort each ele- or alternative into acceptable and unptable categories.

There are at least two limitations on method: (1) on the number of variables that the human mind can manage in synthesizing an image of the alternative being described; and (2) the more variables used and the more categories on each scale, the larger is the sample space of plausible alternatives. This may cause a sparse sampling rate because the number of individuals that can be interviewed and/or the number of alternatives that each individual can process are limited. Such a sampling rate might not be sufficient to determine the threshold function.

Once the alternatives have been sorted by the subjects, there are several methods that might be used to estimate individual or aggregate threshold functions. We focus on the individual threshold function because aggregate estimation techniques still are being developed.

Discriminant analysis (Cooley and Lohnes 1971) is a very powerful technique for estimating the individual threshold function. Using metric variables (measured on interval or ratio scales), nonlinear discriminant functions can be estimated and tested based on hypotheses about the functional form. One form that has proven to be particularly successful is the general quadric function (deBettencourt and Peterson 1976). Using nonmetric or categorical variables (See *Scale Definitions*) dummy variable discriminant analysis can be used. Discriminant analysis is applied to the two populations of alternatives obtained by the sorting procedure, the acceptable alternatives, and the unacceptable alternatives. The resulting discriminant function is an estimate of the equation of the boundary between the two sets, with appropriate adjustments. This is a nonconventional application of the method and many of the conventional statistical interpretations of the discriminant analysis may not be strictly applicable.

Bayesian classification methods (Miller and Freund 1965) have also been applied with some success to model the threshold relations. One advantage of using such an approach is that you don't directly specify the functional form of the threshold function.

RESULTS OF ILLUSTRATIVE PILOT STUDIES

The experiments conducted using two individuals with six scales each having six

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WILD RIVERS PROJECT     NORTHWESTERN UNIVERSITY     EVANSTON, ILL. 60201

ON THE FOLLOWING PAGES, YOU WILL BE PRESENTED WITH A NUMBER OF DIFFERENT
RIVER RECREATION SITE DESCRIPTIONS.  WE WOULD LIKE TO KNOW IF YOU WOULD FIND
THESE SITES ACCEPTABLE LOCATIONS FOR THE SAME ACTIVITY WHICH BROUGHT YOU TO
THIS AREA.  MARK YOUR ANSWER BY CHECKING EITHER THE BOX LABELED ACCEPTABLE OR
THE BOX LABELED UNACCEPTABLE BELOW THE SITE DESCRIPTION.

1--------------------------------------------------------------- 2499
      WATER CONDITION          FAIRLY CLEAN, DRINKABLE IF NECESSARY
      DEGREE OF DEVELOPMENT    WILDERNESS
      CROWDING/USE             FEW OTHER USERS
      TRASH/LITTER             MODERATELY LITTERED
      SKILL LEVEL REQUIRED     PRACTICED BEGINNER

   THIS SITE WOULD BE   (  ) ACCEPTABLE    (  ) UNACCEPTABLE
2--------------------------------------------------------------- 2499
      WATER CONDITION          UNDESIRABLE QUALITY, UNDRINKABLE
      DEGREE OF DEVELOPMENT    RURAL AGRICULTURAL/RECREATIONAL
      CROWDING/USE             FEW OTHER USERS
      TRASH/LITTER             LITTLE VISIBLE LITTER
      SKILL LEVEL REQUIRED     BEGINNER

   THIS SITE WOULD BE   (  ) ACCEPTABLE    (  ) UNACCEPTABLE
3--------------------------------------------------------------- 2499
      WATER CONDITION          UNDESIRABLE QUALITY, UNDRINKABLE
      DEGREE OF DEVELOPMENT    NON-WILDERNESS BACKCOUNTRY
      CROWDING/USE             NO OTHER USERS
      TRASH/LITTER             HEAVILY LITTERED
      SKILL LEVEL REQUIRED     BEGINNER

   THIS SITE WOULD BE   (  ) ACCEPTABLE    (  ) UNACCEPTABLE
4--------------------------------------------------------------- 2499
      WATER CONDITION          UNDESIRABLE QUALITY, UNDRINKABLE
      DEGREE OF DEVELOPMENT    RURAL AGRICULTURAL/RECREATIONAL
      CROWDING/USE             A LARGE NUMBER OF USERS
      TRASH/LITTER             NO LITTERING AT ALL
      SKILL LEVEL REQUIRED     PRACTICED BEGINNER

   THIS SITE WOULD BE   (  ) ACCEPTABLE    (  ) UNACCEPTABLE
5--------------------------------------------------------------- 2499
      WATER CONDITION          PURE, CLEAN, DRINKABLE WATER
      DEGREE OF DEVELOPMENT    URBANIZED AREA
      CROWDING/USE             NO OTHER USERS
      TRASH/LITTER             NO LITTERING AT ALL
      SKILL LEVEL REQUIRED     EXPERT

   THIS SITE WOULD BE   (  ) ACCEPTABLE    (  ) UNACCEPTABLE
6--------------------------------------------------------------- 2499
      WATER CONDITION          PURE, CLEAN, DRINKABLE WATER
      DEGREE OF DEVELOPMENT    RURAL AGRICULTURAL/RECREATIONAL
      CROWDING/USE             FEW OTHER USERS
      TRASH/LITTER             MODERATELY LITTERED
      SKILL LEVEL REQUIRED     BEGINNER

   THIS SITE WOULD BE   (  ) ACCEPTABLE    (  ) UNACCEPTABLE
7--------------------------------------------------------------- 2499
      WATER CONDITION          CLEAN ENOUGH TO USE, BUT UNDRINKABLE
      DEGREE OF DEVELOPMENT    RURAL AGRICULTURAL/RECREATIONAL
      CROWDING/USE             A MODERATE NUMBER OF USERS
      TRASH/LITTER             MODERATELY LITTERED
      SKILL LEVEL REQUIRED     BEGINNER

   THIS SITE WOULD BE   (  ) ACCEPTABLE    (  ) UNACCEPTABLE
```

Figure 6.--*Sample questionnaire format.*

tegories; thus, a sample space of 46,556 ternatives was generated. The two individ-ls each were given 100 randomly sampled ternatives to sort. Stepwise discriminant alysis available in the SPSS package (Nie *al.* 1975) was used to estimate the thresh-d functions. The discriminant analysis s used under three different variable ansformations: (1) linear, (2) quadric, d (3) dummy variable (binary).

The following tabulation shows the lative ability of the three functions to rrectly separate the sorted alternatives r the two subjects:

	Individual ZH	*Individual DK*
	- - - - - Percent	- - - -
near	85	93
del Quadric	93	93
mmy Vbl	93	93

Figure 7 shows some two-variable par-al plots of the threshold function for e two individuals. The plot for individual 's dummy variable function demonstrates scontinuity problems that might arise ther from improper scale definition or om sparse sampling. Nevertheless, the mmy variable and quadric functions were le to predict 93 out of 100 decisions rrectly for each of the two individuals.

Based on these and other pilot studies, e scales and variable sets shown in the x below were developed.

In another pilot study intended to help fine the actual questionnaire design, 15 ople participating in white water kayaking re interviewed on the Wolf River in Wis-nsin. Each of the 15 individuals was esented with 20 randomly generated alter-tives, using the variables and scales own in the box. Because of the specialized ture of the activity in which they were gaged, these kayakers were assumed to mprise a homogeneous population. Their mbined responses comprise a set of 300 ternatives from a sample space of 1,024 ssibilities (29 percent).

Discriminant analysis again was used; is time in an attempt to estimate a single reshold function for the group of 15 in-viduals, based on their combined responses. near, quadric, and dummy variable trans-rmations were used. Two Bayesian classi-cation techniques also were tried out.

The following tabulation shows the percent correctly classified:

Continuous models	*Correctly classified* (Percent)
Linear	72.3
Quadric	73.0
Discrete models	
Dummy var.	74.3
Bayes	72.7
Bayes with Interaction	73.3

These results indicate that (1) there is not much difference in this case, the five methods don't differ much, (2) the concept of a group threshold function does exist, but (3) the boundary is less well defined for this group of 15 individuals than it is for a single individual. This indicates that the group is not perfectly homogeneous, but that there is considerable commonality among the individual decision rules.

Scale Definitions

Scale 1: WATER CONDITION
1. Pure, clean, drinkable water
2. Fairly clean, drinkable if necessary
3. Clean enough to use, but undrinkable
4. Undesirable quality, undrinkable

Scale 2: DEGREE OF DEVELOPMENT
1. Wilderness
2. Nonwilderness backcountry
3. Rural agricultural/recreational
4. Urbanized area

Scale 3: CROWDING/USE
1. No other users
2. Few other users
3. A moderate number of users
4. A large number of users

Scale 4: TRASH/LITTER
1. No littering at all
2. Little visible litter
3. Moderately littered
4. Heavily littered

Scale 5: SKILL LEVEL REQUIRED
1. Expert
2. Intermediate
3. Practiced beginner
4. Beginner

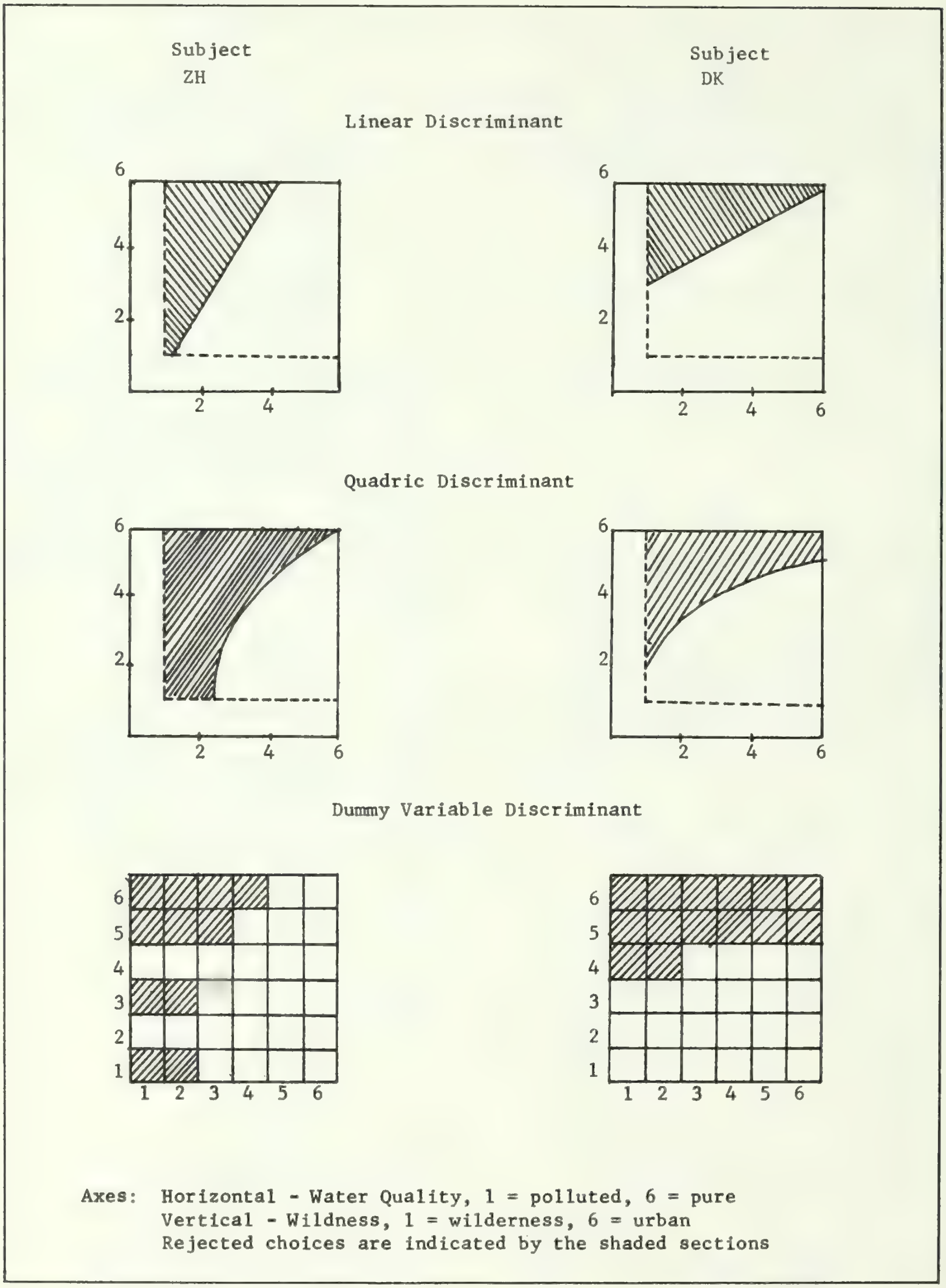

Figure 7.--*Conditional threshold diagrams for experiments with two individuals.*

Figure 8 gives partial plots for the functions. These plots are two dimenal slices of five dimensional functions. ite the apparent dissimilarities, there significant common characteristics. differences can be explained mathematiy.

All of these results are presented by of illustration only, and should not be rpreted or applied beyond that purpose. work at the Pine River this summer (1976) produced a data set of approximately 400 viduals who have responded to unique sets 5 alternatives. When those data have analyzed, we will be able to report conclusive results, both by way of uating the methodology, and by way of rting specific criteria that can be used river evaluation.

APPLICATIONS AND FURTHER RESEARCH

The formulation of user-based criteria standards for evaluation of recreational lities is an important part of the plan-, design, and management of recreational ronments. The techniques discussed show iderable promise of usefulness if they be adequately defined, developed, and dated. Potential functions include the owing:

(1) User-based standards of adequacy, erms of environmental variables, for ous recreational purposes and types of s. Such standards would be helpful in designation and management of recreationites.

(2) Diagnostic information on the ennmental reasons for a site's attractive- or unattractiveness to various groups different recreational purposes. Such rmation provides useful contributions he problems of predicting demand, designa-, modification, and design of sites, gement of demand, and user education.

(3) Information on the relative availity of specific sites or kinds of sites a-vis the requirements of social groups demand sectors.

(4) Explanation of the relative imance of different environmental attris from the user's point of view. The shold function, whether individual or aggregate-probabilistic, gives an indication of the shape of the utility function, especially the substitution or trade-off relations among the significant environmental variables that enter the site choice process. The marginal rate of substitution defines the relative importance of the variables at the threshold and indicates the existence of hierarachical dominance, if any. The techniques presented here allow nonlinearities to be described, thus preserving variable rates of substitution.

We have applied these concepts successfully to fishing, cross-country skiing, rafting, and shopping center destination choice. More research is needed, however, if these kinds of user-based evaluation standards are to be accepted and used by managers.

Pertinent research topics can easily be identified. In the context of the experimental technique, the methods of environmental display need to be studied, improved, and validated. Our selection of scales and variables to describe the site, although based on extensive conceptual and empirical research, does not necessarily represent the universe of important variables, nor are the scales necessarily the best. What is the "mental language" used by recreationists to think about their recreational environments? Have we adequately captured that language, or are there more or different variables and must the scales be reconstructed? How do we translate these "macro-level interpretive" variables of mental language into tangible site characteristics that managers can understand and work with? Actual stream management must be done in terms of streambank erosion, physical measures of water quality, etc. The user's perceived quality is defined in rather different, more general and interpretive terms. Fortunately, the Pine River research has been designed to cooperate with some rather extensive physical inventory work (Chubb and Bauman 1976), so we have some opportunities for "bridge building".

Another important issue concerns the possibility that the experimental process may force the subject into an unrealistic decision situation, thereby distorting his evaluative rules. Can thresholds actually be identified, and if they can be identified, do they realistically describe actual de-

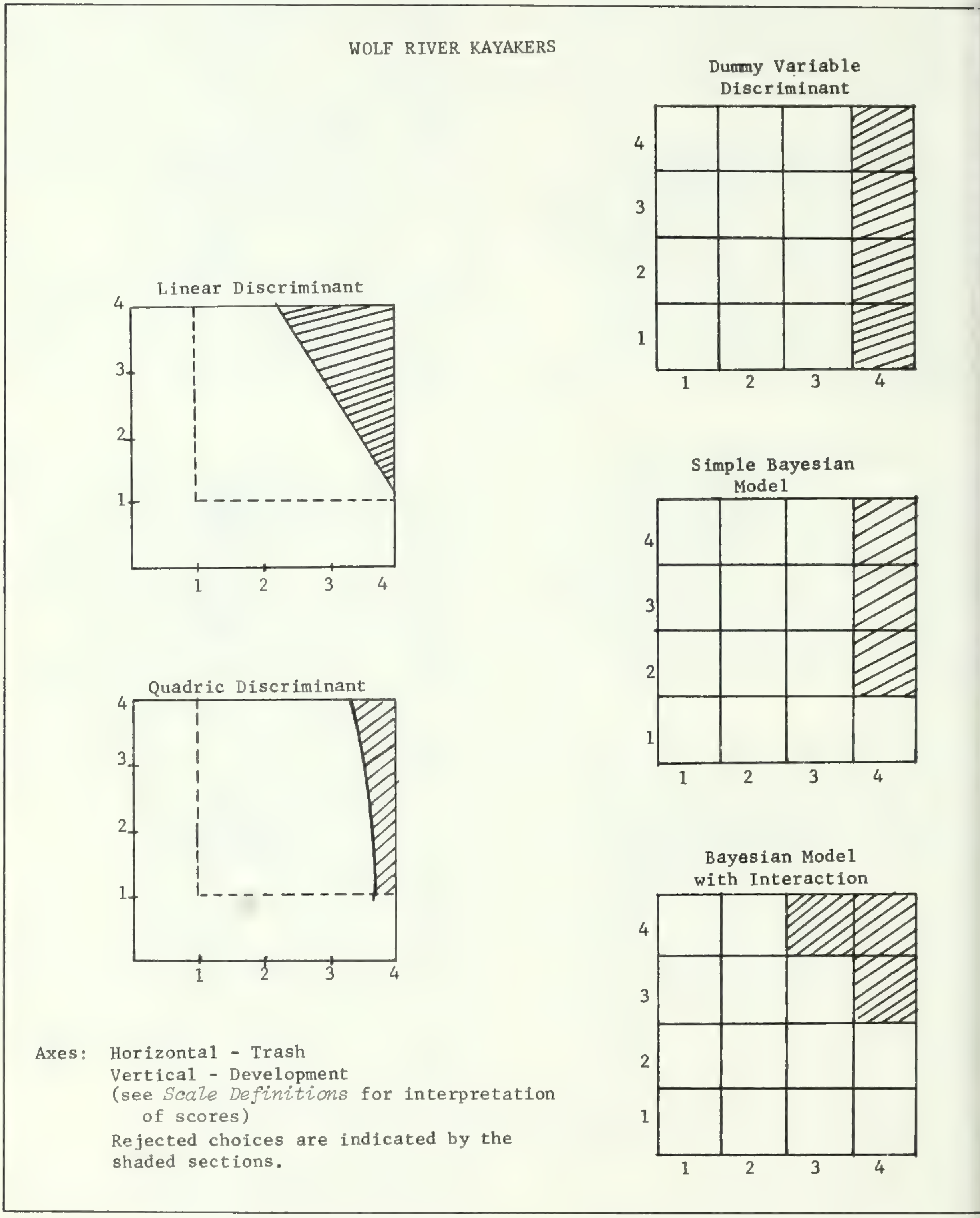

Figure 8.--*Conditional threshold diagrams for a single group experiment.*

sion-making behavior, or are they arti-
cts of a contrived experiment?

Assuming that the threshold function
ncept is a valid way to describe recre-
ional site choice, do the locations actu-
ly being used by recreationists fall into
eir acceptable resource category, or is
ceptability dependent on the richness of
e set of available alternatives? When
cceptable" sites, as defined in the thresh-
d function experiment, simply are not
ailable, do people accept "unacceptable"
tes rather than forego a desired recreation-
activity.

These and other questions about statis-
cal methodology can be resolved only through
pirical research of the type we have been
nducting. Our studies at the Pine River
d at other locations are expected to shed
light on many questions.

Even if the proposed methods and concepts prove to be valid, there remains two other questions that are not really research issues. Is there a real need for user-based evaluative criteria. If there is, will managers and decision-makers be willing or able to make use of them? Surely, there are valid arguments against basing resource management exclusively on the preferences and perceptions of users. In recreation, this could lead to the destruction of irreplacable opportunities and interference with competing but important activities. However, the point is not that management of recreational resources should be determined by users' criteria but that management understanding the users' point of view is more enlightened and can do a better job, whatever the mission and whatever decision criteria actually end up being used.

A SURVEY AND ANALYSIS OF RECREATIONAL AND LIVESTOCK IMPACT ON THE RIPARIAN ZONE OF THE RIO GRANDE IN BIG BEND NATIONAL PARK

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ABSTRACT--Visitor usage patterns, biological conditions, and selected parameters of recreational impact (including litter, trampling, tree cutting, and human waste) were measured over a 12-month period. Use and impact were shown to be strongly and positively correlated. However, recreational impact was not significantly related to biological health of the area. Cluster analysis was used to group areas into three categories based on degree of impact; only one of every four sites was indicated as heavily impacted. Principal components analysis identified human impact parameters as best discriminators between sites.

In recent years, the Rio Grande of the Big Bend National Park (BBNP) has experienced dramatic increases in recreational and water resource use. Thus, the National Park Service (NPS) has found it necessary to secure information concerning the actual and potential impact on the river and on associated land area ecosystems from present levels of human usage.

The primary goals are to assess the impact upon the Rio Grande Floodplain in BBNP to provide baseline data for determining the "carrying capacity" of the area, use management alternatives, and strategies that may be employed to ensure that use remains within this carrying capacity.

Four factors are being investigated as follows:

1.--Resource

(a) Preliminary biotic survey of the riparian areas along the Rio Grande.

(b) The identification, distribution, and relative abundance of plant and mammalian species in riparian areas along the Rio Grande.

2.--Users

(a) To identify the extent, character, and patterns of recreational use along the Rio Grande corridor.

(b) To identify the geographic and descriptive characteristics of recreational users by user group.

3.--Impacts

(a) To determine the direct and indirect impact of human use upon plant and mammal life and other natural resources.

(b) To formulate recommendations for short-term and long-term monitoring programs of biological resources.

4.--Management

(a) To formulate recommendations for additional research needs.

(b) To suggest alternatives for management schemes aimed at maintaining and perpetuating the natural ecosystems in consonance with current NPS natural area policies.

APPROACH

After study of aerial photographs, float trips were conducted from Lajitas to La Linda and 64 major riparian areas were identified and recorded on a map. For statistical analysis purposes, each was treated as a distinct sampling entity, although they tend to form a continuum along the river (fig. 1).

Most of the riparian areas are accessible only by river. However, 26 riparian sites may be reached by roads: 18 of these are reached by a dirt road called the River Road, which becomes impassible during rainy weather. These 18 have been designated as primitive campsites. There are also eight sites that are accessible via paved roads; two (Cottonwood and Santa Elena Picnic Area) are small campgrounds and a third (Rio Grande Village) is a major campground.

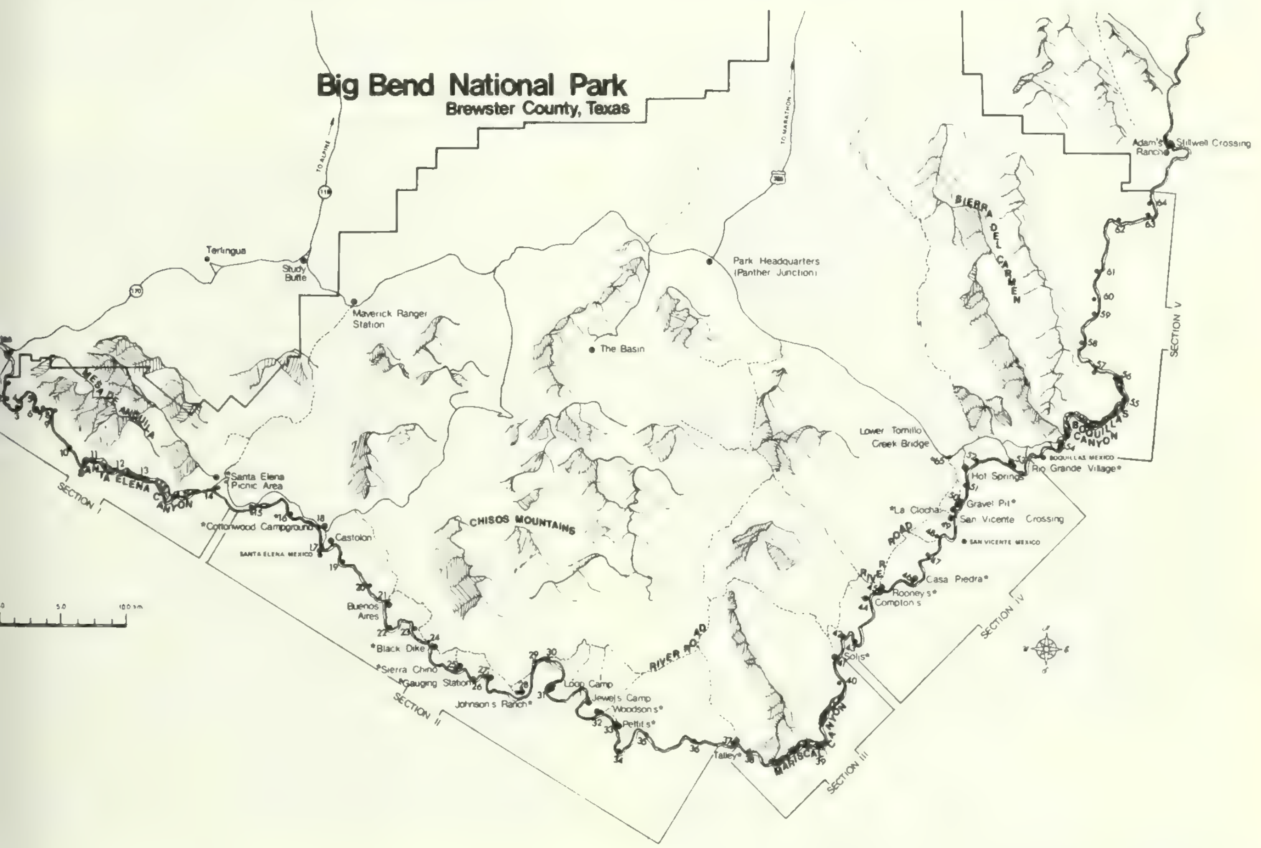

Figure 1.--*Map of the Rio Grande River corridor in BBNP showing the 64 riparian sites investigated during this study. Name places along the river represent backcountry campsites as designated by park officials. Sites with stars represent places where the rodent fauna was sampled. The five river sections discussed in the text are labeled.*

The river was divided into the following five sections based on the location of the three major canyons (fig. 1): I from Lajitas to the mouth of Santa Elena Canyon (including the canyon itself); II from Cottonwood campground to Talley; III from Talley to Solis (including Mariscal Canyon); IV from Solis to Rio Grande Village; and V from Rio Grande Village to the eastern border of the park (including Boquillas Canyon).

RIVER USE

Use occurs both throughout the park's backcountry and at three developed campgrounds where use is already carefully monitored. Use of the backcountry areas, however, is not clearly described by existing record-keeping procedures.

Because almost all of the river corridor lies in the backcountry, our analysis of visitor use patterns focused on backcountry use. Visitors to Big Bend are required to obtain a free permit from park headquarters or any ranger before camping at any backcountry area or floating the Rio Grande, which they turn in at the conclusion of their trip. The primary purpose of this backcountry information system is to facilitate visitor protection.

This system was used as the data base for establishing the extent, character, and patterns of use. The Park Service compiled these data monthly in three categories: nature road use (i.e., camping at primitive campsites with road access); backcountry use (nonvehicular); and boating use (including all forms of water craft). In our analysis, we separated backcountry use of the river from backcountry use of other areas and divided river use into float trips and nature road (River Road) use. Within these two categories, analysis yielded user group-, time- and place-specific information.

We recorded the data using three units of measure: (1) number of parties, (2) number of individuals, and (3) number of man-days. This provided a comprehensive view of use as well as insight into the best measure for establishing human impact. During the project study year (1975), the distribution of backcountry use is shown in table 1.

Table 1. *Distribution of visitors with Big Bend National Park backcountry area 1975*

	Parties	Total parties	Man-days	Total days
		Percent		*Perce*
Float trip	727	18.7	7,405.5	25.
River road camping	849	21.8	7,151.0	24.
Nonriver-oriented camping	2,318	59.5	15,124.5	50.
Total	3,894	100.0	29,681.0	100.

Table 1 shows that the Rio Grande attracts approximately 40 percent of tot backcountry use (parties) while the dese and mountains account for nearly 60 perc Using the man-days measure, however, the amount of river-oriented backcountry use almost equal to the nonriver-oriented camping category.

Float trip and River Road camping patterns were analyzed further because t activities account for nearly all of the recreational use that is associated with Rio Grande corridor in BBNP.

Float trip activity was broken down according to the functional river subsys (fig. 1). The distribution of float tr across the 5 river subsystems in 1975 is shown in table 2.

The three canyons accounted for 69 percent of the total float trip parties visiting the Rio Grande Corridor in 1975 (table 2). The 25 percent figure for IV be explained largely by short day-floats. Using the man-days measure, the three canyons collectively account for 81 perce of all float trips within BBNP. This is better measure of the distribution of use and related impact on the river corridor because it reflects both the actual numbe of visitors and the time they spent on th river.

A seasonal dimension was obtained by breaking down use by month because of its value for on-site decision making. This time-and place-specific monitoring of dat should signal management as to when use problems are likely to occur.

'ab e 2.--*Distribution of float trips hrughout the Rio Grande subsystems in BN in 1975*

ec on[1]	Parties	Total parties	Man-days	Total man-days
		Percent		*Percent*
S ta le a				
an on	186	22.1	1,637.7	22.1
I between an ons)	50	5.9	278.7	3.7
II Mariscal an on	258	30.7	2,464.5	33.3
V between an ons)	210	25.0	1,130.4	15.3
B quillas an on	137	16.3	1,894.5	25.6
	841[2]	100.0	7,405.5	100.0

[1] See map (Fig. 1)
[2] Total does not agree with total numer of float trip parties in table 1 because parties could have floated more the one river section.

The River Road camping category also as roken down on a site-by-site and ontly basis. Camping at designated rimtive River Road campsites in Sections I ai IV was concentrated at very few ite. Two River Road sites (Gravel Pit nd olis) accounted for 39 percent of ota annual River Road site use (man-days) n 175. Four more sites (Johnson Ranch, lac Dike, Talley and San Vicente Crossing) cccnted for an additional 32 percent of ota annual River Road use (man-days). igh of the more remote River Road sites eceved less than 2 percent each.

Float trips occur mainly in Sections I, II, and V and River Road Camping is limited o dsignated areas in Sections II and IV xcet at two of the River Road campsites, ally and Solis, which also serve as the ut-n and take-out points, respectively, or he popular Mariscal Canyon Float rip Thus, these sites are the most eavly used areas of the entire back-ourry riparian corridor. In addition, hey are areas where floating and car amping activities overlap.

SUBJECTIVE SITE EVALUATION

A subjective site evaluation sheet was eveoped as shown in figure 2. The four basic categories are: human impact (six different variables); livestock impact (two variables); site description (three variables); and wildlife characteristics (four variables). Each of the 15 variables is rated on a scale from 1 to 5: 1 represents the most desirable condition; 5, the least desirable condition. For example, 1 is assigned if no litter is present; 3 if litter is apparent; and 5 if litter is obvious everywhere. Scores of 2 and 4 are also possible. Totals were obtained for each of the four major categories. Thus, the total score for the human impact parameter could range from 6 to 30: 6 would indicate no human impact; 30 very heavy impact.

Data were obtained by visiting each of the 64 riparian sites. The number of visits per site varied from one to four and the number of persons filling out the impact forms varied from two to six. Scientists, students, and park personnel filled out the impact forms separately.

Statistical analysis of data provides a powerful "tool" upon which to base managerial recommendations. In working with large data bases, analyzing each variable individually becomes cumbersome and fails to account for the fact that variables often act together to affect a particular condition. For example, tabulation of the site evaluation sheets resulted in a large data base in the form of a 64 X 15 matrix (64 sites, 15 variables), which would be difficult to analyze by considering each variable separately. Multivariate statistics, however, allows one to analyze such a matrix by considering each variable for each site simultaneously. We used two multivariate approaches (cluster analysis and principal components analysis) to structure the site evaluation data base. The following two examples illustrate the utility of multivariate statistics in analyzing data for use in formulating managerial recommendations.

A cluster analysis was used to produce a phenogram that represents a grouping or ordering of sites (based on all 15 variables) closely connected by some relation and separated from other such groups by gaps. The cluster analysis (fig. 3) reveals three major clusters, A, B, and C. Cluster A includes those sites with high impact values; cluster B, those with intermediate impact values; and cluster C, those with

Observer: ____________________ Profession: ______________

Date: __ __/ __ __/ __ __ River site (no.): ________
day month year

River side: M or A

Site class: A, B, C

PARAMETER | RATING | COMMENTS

A. MAN'S IMPACT

Litter	
Trampling	
Rock moving	
Campfire	
Human waste	
Wood cutting	
TOTAL	

B. LIVESTOCK IMPACT

Trampling	
Waste	
TOTAL	

C. SITE DESCRIPTION

Access	
Shoreline vegetation	
Campsite potential	
TOTAL	

D. HABITAT TYPES (check those present)

_____riparian
_____dune
_____gravel beach
_____bench
_____talus slope

E. WILDLIFE CHARACTERISTICS

Habitats	
Unique combinations	
Modifications	
Values and needs	
TOTAL	

Figure 2.--*Rio Grande ecological survey riparian community evaluation sheet.*

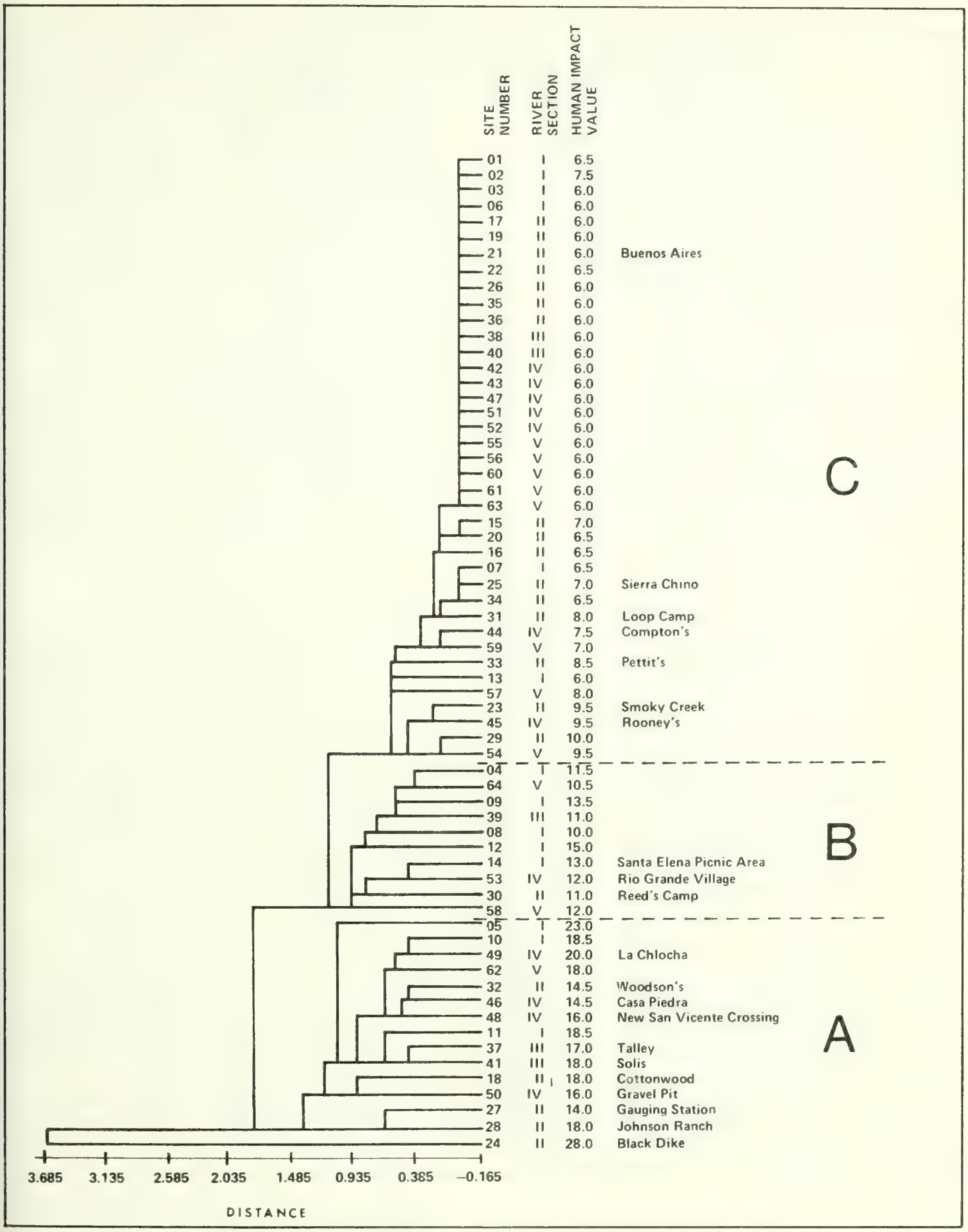

Figure 3.--*Phenogram of numbered riparian sites computed from distance matrices clustered by unweighted pair-group method using arithmetic averages (UPGMA). The major breaks in the phenogram are labeled A, B, and C. The river section and total human impact value for each site are also provided.*

low impact values. Of the 64 sites, 15 (23 percent) fall within cluster A; 10 (16 percent) within cluster B; and 39 (61 percent) within cluster C. Of the 15 sites in cluster A (heavily impacted sites), 11 (70 percent) can be reached by the River Road; whereas of the 39 sites in the least impacted cluster (C), only 7 (18.0 percent) are accessible by the River Road. So the cluster analysis reveals that (1) very few of the riparian sites may be considered heavily impacted; and (2) the majority of the heavily impacted sites are those that may be reached via the River Road.

Principal components analysis (PCA) was used to identify linear combinations of the 15 variables that account for the greatest amount of variation among sites. Principal components I and II account for 56 percent of the total variance and each of the sites is plotted with respect to these components in figure 4. Variables that load heaviest on component I (that is, those variables which account for th greatest amount of variation among ripar sites on this component) are those that relate to human impact and modification (table 3). Component II loads heavily o variables that relate to site descriptio The loadings for those variables reflect livestock impact are very low on the fir two components. This indicates that liv stock impact accounts for very little of differences among sites: hence, it is a constant along the entire river corridor The major breaks along component I are depicted by lines A and B in figure 4. Sites to the right of A are the most hea impacted ones and they correspond exactl with the heavily impacted sites in the cluster analysis. Sites between lines A B include those that fall in the intermediate impacted category of the cluster analysis. Sites to the left of line B a those that fall into the lightly impacte

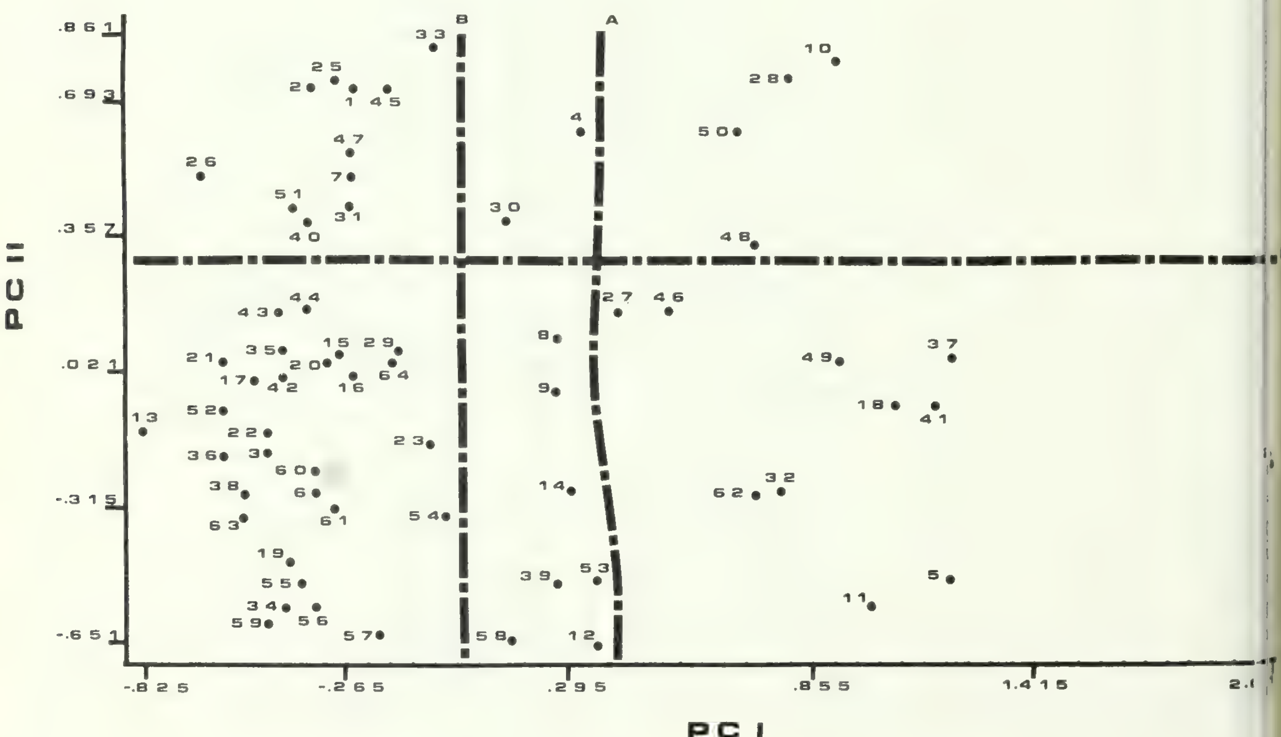

Figure 4.-- *Two-dimensional projections of the first 2 principal components illustrating the position of the 64 riparian sites. Each component represents linear combinations of all 15 variables in proportion to their importance in distinguishing sites. Lines A and B are positioned where the major breaks occur along component I; line C demarks the major break along component II.*

Table 3.--*Factor matrix (or loadings) from correlation matrix among 15 variables for the first two Principal Components. The higher the value for a particular variable the more important that variable is for distinguishing sites.*

Variables	Principal components I(37.44 percent)	II(17.92 percent)
Man's Impact		
Litter	.882	-.136
Trampling	.900	.064
Rock Moving	.864	-.077
Campfire	.868	-.110
Human Waste	.838	-.047
Wood Cutting	.821	.054
Livestock Impact		
Trampling	.305	.475
Waste	.351	.264
Site Description		
Access	.068	.865
Shoreline Vegetation	.148	.797
Campsite Potential	-.279	.763
Wildlife Characteristics		
Habitats	-.106	-.099
Unique Combinations	-.066	.432
Modifications	.851	.181
Values and Needs	.300	.390

ıster. The major break along component is indicated by line C. Sites above this ıe have excellent campsite potential; :es below this line have poor campsite :ential. Considering the two components ;ether reveals a group of eleven sites in : upper left-hand quadrate of figure 4 ıt are characterized by having excellent ıpsite potential and low human impact.

Combining the results of the cluster ılysis with that of PCA reveals the lowing: (1) Those variables that best :criminate riparian sites are those ating to human impact and modification. sites may be segregated into three ;ic groups (lightly impacted, moderately ıacted, and heavily impacted) on this basis. (2) Variables pertaining to livestock impact are poor discriminators of riparian sites; this indicates that this impact is a constant along the entire river corridor. (3) Very few of the riparian sites may be considered heavily impacted; of these, the majority are distributed along the River Road. (4) A group of sites can be identified that have excellent campsite potential yet very little human impact.

BIOLOGICAL RESOURCE

The biological resource monitored along the river corridor was the rodent fauna and vegetation. Rodents were chosen because: (1) the riparian habitat is the

only major vegetation type in the park in which rodents have not been intensively studied; and (2) rodent densities should be sensitive indicators of significant human and livestock impact. Rodent densities are strongly influenced by vegetative "cover" (spacing and size of the plants). Many types of human and livestock impact (especially trampling) tend to reduce cover. Hence, if severe enough, they could greatly influence the diversity and density of rodents. We sampled the riparian rodent fauna at 18 different sites along the river that exhibited varying degrees of human and livestock impact. Seventeen of these sites were designated as backcountry campsites along the River Road; the other site was located at lower Tornillo Creek bridge. Each site was trapped for 6 nights using 120 Sherman live traps (720 trap nights per site).

Twelve species of rodents occur in the riparian habitats of BBNP and the majority of these (9) are members of the families Heteromyidae and Cricetidae. The remaining three (porcupine, spotted ground squirrel, and beaver) either occur in numbers so small that they are seldom encountered or they are so large they cannot be adequately sampled with the techniques available to us. The total number of cricetid and heteromyid rodents captured at a particular site was used as an indicator of rodent density. Rodent densities (total catches) were then correlated with human and livestock impact values as follows (values represent Pearson Product-Moment Correlations):

	Human Impact	*Livestock Impact*
Heteromyid	-0.177	-0.321
Cricetid	.088	.152
Total	-.071	-.133

None of the correlations between rodent density and human or livestock impacts are significant. Hence, our data suggest that the present extent of impact along the river has not been great enough to significantly affect rodent densities.

MANAGEMENT IMPLICATIONS

Analysis of recreational use patterns or subjective impact alone is of little managerial importance. They need to be campared to determine if a significant correlation exists. The Pearson Product Moment Correlation Coefficient statistic used to relate total subjective impact ratings by site to annual camping use by site (man-days). The analysis was only possible where we have permit data on use namely, for the River Road sites. Howeve these sites are the only locations where significant use of the river corridor occ Analysis revealed a positive correlation significant at between the 0.02 - 0.05 (R=0.459) levels. This verifies that subjectively evaluated impact increases a use increases.

When impact and use data were relate to biological data (rodent fauna studies) no significant correlations were yielded. The upshot of these two correlation analyses taken together is that site impa have occurred as a result of recreational use, but not to the point where ecologica conditions, as indicated by the biologica health of rodent fauna, are in jeopardy.

This suggests that these correlation should be viewed in the context of "chang rather than "impact" (which implies damag Any recreational use of a resource will result in some change in resource conditi The critical task for management is to decide what is the acceptable level of physical-biological change. This require value judgement as to the *desirability* of changes that are anticipated or have alre occurred; i.e., is there excessive deviat from the accepted standard of resource quality? And this acceptable level of ch depends on the management objectives of t area.

Plugging study findings into this ty of framework yields several observations. Subjective impact ratings do reflect chan from natural ecological conditions, and t *relative* amount and type of change by sit Correlation analysis links this change to levels of use intensity. The task remain for management is to evaluate the acceptability of the situation that has been identified.

When viewed from a National Park Service-wide perspective, the total recreational use of BBNP and the Rio Grand appears very low. This might lead one to the casual and incorrect conclusion that

ecreational impact on the river corridor
s not really a problem. This study disaggregates possibly misleading total use
igures into area-specific and time-specific
ata sets that indicate when and where
hanges exist within the river system and
ow serious the changes are. While it
ppears that existing changes have not yet
eached the point of constituting serious
cological damage, the changes have been
easured in terms of parameters that can be
eadily perceived by visitors and that are
menable to management. Hence, the observed
hanges, if deemed undesirable or excessive
 management, can be reversed before they
ead to serious damage.

Earlier, when total subjective impact
ores for 64 river sites were clustered,
 sites or 77 percent were in the moderely and lightly impacted clusters. Looking at the River Road sites, it is revealing
 note that 10 of 18 are shown in the
avy impact cluster. These 10 are all
nerally related to convenient access; i.
, close proximity to a paved park road or
ecial attractions like the entrance to
nta Elena, Johnson's Ranch, and Mariscal
nyon. Access can therefore be verified
 a major component in explaining variation
 human impact. While this verification
ould not be too surprising, it does
phasize the role access plays in distriting human impact.

These impacts can be controlled,
aped, or mitigated because access can be
sily manipulated. This is particularly
ue in Big Bend where use of sites on the
ver Road is concentrated at 6 sites
ccounting for 71 percent of total annual
ver Road use). Here a washed-out road
y be naturally responsible for reducing
e at one of the most impacted sites.
liberate management strategy can have the
me result. Use can be rotated among sites
ther explicitly through permit allocation
 implicitly through ranger's suggestions
en asked by a party where they should
mp. Impacts can be reduced and distrited once management goals are established.

For example, we know how many River
ad campsites are among the heavily impact-
 campsites (10 of 18). Further, princil components analysis indicates that the
emaining River Road campsites all possess
od campsite potential (also rated subectively, figure 2) although they are
ghtly impacted. In other words, the
spectrum of suitable campsites available to the River Road user includes 10 heavily impacted and 8 moderately or lightly impacted areas. Is this acceptable? What should the distribution be among the light, moderate, and heavily impacted clusters? Should there be no heavily impacted sites or should sites be equally distributed among these impact clusters? Once this is decided by management, we might know how to respond in terms of impact expected if, for example, the River Road is paved (as has been proposed). Clearly, given our understanding of the correlation of impact and use and the role played by access, increased use of all sites is likely to occur with associated human impacts. Further, human usage may increase to the point where use impacts are a source of significant ecological impact.

In the past, investigators have often done good, thorough research only to find that their results had little effect on resource management. This has occurred because researchers have failed to articulate their findings in terms that are useful to management personnel. It has been our goal to obtain the types of data that BBNP managers need and to present it in such a way as to serve as a useful input to normal managerial decision-making.

Consequently, our recommendations focused on suggesting ways to incorporate study findings into the process of determining management strategies that will achieve the objectives sought. Based on a review of pertinent literature relative to resource allocation decision-making, several critical decision points can be identified:

Decision 1.--Select management objectives
Decision 2.--Determine whether existing situation conflicts with management objectives
Decision 3.--If a discrepancy exists, select management tools and strategies to meet objectives
Decision 4.--Evaluate results of implementation of management strategies, including monitoring of environmental conditions.

Clearly, the selection of management objectives serves as the basis of the

entire suggested decision-making framework. This is the responsibility of NPS management personnel. Findings from this research, though, should play an important role as an input to Decisions 2 and 3, while additional research will be needed in the future before Decision 4 can be considered.

ACKNOWLEDGMENT

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PROBLEMS OF DEFINING AND MEASURING THE PREFERENCES OF RIVER RECREATIONISTS

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ABSTRACT.--The paper discusses seven broad types of problems experienced by the authors during their research on the preferences of recreationists using three rivers in Michigan. Those problem areas concerned the tasks of: selecting variables to be included in research designs; deciding which research approach is the best suited for particular purposes; designing sample plans; collecting data in the field; understanding the dynamics of human preference formation; defining the word preference; and specifying clearly the preferences to be studied. Recommendations for helping solve these problems are offered.

Most outdoor recreationists prefer to near, in, or on water, including rivers, : their preferences are not easy to quan- 'y. This paper discusses the principal oblems we have encountered attempting to entify and measure the preferences of rec- ationists using three rivers in Michigan Bassett *et al.* 1972 , Knopf *et al.* 1973 , ver and Bassett 1975). Other research- ; have experienced similar problems, so we e no pretense to be original. Instead, objectives of the paper are to outline e of the familiar problems, and then dis- s in detail two related areas that we ieve are more complex in river recreation earch than is commonly recognized. These blems are defining clearly what is meant the word "preference" and specifying the cise types of preferences that are being sured. We will begin with a brief over- w of five problems common to all research- : selecting appropriate variables, decid- how to measure variables, designing an icient sampling scheme, collecting data the field, and gaining an adequate back- und understanding of human preference mation.

SELECTING VARIABLES

Water-based recreation, especially on ers, encompasses great diversity in use in users. This diversity poses unusual problems in experimental design, particularly in identifying appropriate variables to measure and in devising ways to measure them. For example, recreation-related river uses include many activities such as different types of fishing, various kinds of boating (including water skiing), swimming, ice skating, waterfowl hunting, and various shoreline activities, including picnicking and viewing. This list of uses is compounded by the fact that some activities are not uniform with respect to when they occur (time of day, day of week, or season of year), where they occur (on shore, or in or on the water), and in skill or equipment required. For example, in our current Huron River study we have found it difficult to differentiate a river user from a user of the shoreline facilities in the Huron-Clinton Metropolitan Authority's parks that border on that river.

Moreover, the users themselves differ with respect to age, sex, income, stage in family-life cycle, occupation, education, home and work environment, distance travelled, and past-experience level. Also, it matters whether users are local residents or tourists, and whether they choose a recreation area as their primary destination or merely as a stop while passing through on their way to another spot. These differences among users cannot be ignored because they influence the preferences of those users.

A matrix that includes all combinations of uses and users in a river recreation system will contain more variables than any researcher can afford to sample. The dilemma is deciding what to omit, because the researcher knows full well that omitted variables can influence not only the scope of the research but its quality as well. For example, we found that group size was an important predictor of preferences on the Au Sable River, where many of the canoeists were members of sponsored, organized groups. Had we not determined group size and membership, useful information would have been lost.

MEASURING VARIABLES

Most recreation researchers agree that the preferences of river users should be measured by different research approaches that can serve as cross-checks on each other. Despite this agreement, it is difficult to decide which method of gathering data will give the most valid results in a particular situation. Also, it is difficult to assure that cross-checks will be made because of budget and time constraints and the inability of any one researcher to be knowledgeable about all of the research approaches and the theories behind them. For example, three broad types of research approaches have been identified (Driver 1976b). These consist of techniques that measure: (1) verbal-worded responses, such as those made to a questionnaire; (2) overt nonverbal responses, such as observable behaviors that reveal preferences (e.g., time spent by people doing something, or evidence of trampling at a site); and (3) physiological measures, such as pupillary dilation, pulse rate, or perhaps even brain waves, to correlate preference states with physiological responses.

In our river recreation preference studies, we have relied heavily on the use of questionnaires, despite the many problems associated with their use. We have, however, collaborated with other researchers using other techniques such as User Employed Photography (see the paper by Cherem and Traweek in these proceedings) and have gathered some preference data by unobtrusive observation of the users' on-site behaviors.

SAMPLING

Generally the total population of recreationists is so large that it must be sampled. The many kinds of recreation associated with a river, coupled with the high variability in users themselves, combine to make it difficult for the researcher to design a simple random sample or to stratify the sample and estimate how many samples to take in each stratum. Ideally pilot studies should be conducted to estimate variability of response data, but they often are too expensive simply to be used for designing sample plans. Our approach has been to design our sample plans, using the most reliable information available, and then modify the design after sufficient samples have been collected to make adjustments in the sampling schedules.

Sampling designs that are not modified to reflect information gained after sampling has begun can produce results that are not representative of the preferences of the user population being studied. For example, it might be discovered that some river recreationists tend to cluster, such as in flotillas of canoes or on rafts. Depending upon how they distribute their questionnaires or otherwise measure preference, researchers faced with this situation must decide whether to adjust the sampling frequently and whether to employ cluster-sampling techniques. Another common situation that influences the representativeness of the results occurs when a male-female couple answers a questionnaire together, rather than individually. One "togetherness" response is not the same as one male or one female response.

COLLECTING FIELD DATA

The problems of sample design, although difficult, often are less perplexing than the implementation of the design in the field. For example, we have found that trout fishermen are difficult to contact or even observe because they are in the stream and tend to be active at night or early in the morning. For other recreationists, measurement is often difficult even during the day. Often leaders of raft parties or groups of canoeists, particularly those working for commercial outfitters, may not want interviewers to delay a trip. Moreover, efficient data collection is complicated by the fact that some uses are concentrated in time, such as on weekends or during certain times of the day, or in space, such as at crowded access points.

These field problems frequently require nges and innovations in techniques and eduling which, in turn, can affect the lity of the information being collected bias the results. For example, to ade-tely sample a group of canoeists being hed by livery personnel into a pickup icle at a takeout point, a researcher ht have to use a mail-back questionnaire d possibly get a lower response rate) her than having the questionnaire filled on-site. Or sampling frequencies might d to be adjusted to accommodate increased bers of users at unexpected times, which ht result in an insufficient number of ponses during periods of low use.

UNDERSTANDING THE DYNAMICS OF PREFERENCE FORMATION

The processes by which people form and sue their preferences are complex and amic. For example, it is known that reation preferences are influenced by ious variables in home and work environ-ts and by things that happen while the rs are travelling to the site or while y are actively participating on-site. these reasons, recreation researchers erested in preferences must have a rea-ably good understanding of the dynamics human behavior. Obtaining this under-nding can be difficult, however, because re are many theories of human behavior, luding choice behavior. To help solve s problem, we have adopted the rather eric "problem-solving" model of human avior (Knopf *et al.* 1973 , Driver 6b).

The model is a simple one that views man a complex information-processing and blem-solving organism. Within the model roblem state is defined simply as *a gap ween a person's existing state and a atively more preferred state.* Therefore, life situation is posed as a problem n such a gap exists, and the problem is ved as the gap is closed. The advantage the problem-solving orientation is that makes the concept of preference less tic; it forces us to think about the amics of problem-solving behavior.

The dynamic nature of human problem-ving has been discussed by several au-rs. For example, Miller *et al.* (1960) gest that human problems are resolved her by habitual or heuristic (trial and or or searching) behaviors. Habitual behaviors are ingrained from learning (or from successful problem resolution in the past). White (1959) argues convincingly that repeated mastery has a lasting effect that prompts us to achieve higher levels of competence or mastery in a particular prob-lem situation. This is relevant to recrea-tion preference studies because past expe-rience levels do influence preferences, for activities such as skiing, hunting, fishing, playing chess, or white water canoeing. In contrast, heuristic behavior is employed to resolve novel problems and involves much exploration and seeking of new situations. Obviously, both habitual and heuristic be-haviors are dynamic, and one would expect the preferences of the first-time user to differ from those of the repeat user. In fact, our research indicates that research-ers studying the preferences of river rec-reationists must be aware of differences between first-time and repeat users. The first-time user seems to have less predic-tability than the repeat user about the specific types of satisfactions expected and desired. But even first-time users have considerable information gained from friends and other sources.

Although levels of past recreation par-ticipation do influence recreation prefer-ences, other variables also affect the dynamics of preference formation to a great degree. One category includes the so-called "individual difference" variables, which in-clude user characteristics such as age, sex, income, and education (Driver 1976a). An-other category is the so-called "interven-ing" variables, such as the changing influ-ence of the weather, work conditions, and peer groups on recreation-related prefer-ences. Recreation researchers must be fa-miliar with these influences so they can either control or test for their effects in specific research designs. The absence of such controls may limit the utility of the results and can introduce bias.

Finally, an understanding of the dynam-ics of recreation behavior clarifies the need for the researcher to (1) define clear-ly what is meant by the word preference and (2) understand the various behavioral compo-nents of human preferences. These problems are discussed in the following section.

DEFINING PREFERENCES

A pervasive difficulty in measuring preferences of recreationists is defining

how the word "preference" is used as a variable in a research design. Everyone has an intuitive understanding of what the word means, but if a group of recreationists were asked to explain their concept of preference, they would cite several ideas such as aspiration, demand, desire, expectations, things to be satisfied, value rankings, wants, and perhaps motivations and needs. Survey researchers must therefore be extremely careful that the words chosen to define preferences probe the *same* concepts of *all* the respondents. Otherwise, several preference variables--rather than one variable--are being measured. For example, if the words expectations and values are used synonymously in a questionnaire, the researchers would be tapping at least two different concepts and would never be able to determine what percent of the respondents made which type of interpretation.

To help resolve this definitional problem, we have found the literature from motivational psychology, especially that on Expectancy-value theory, to be useful (Birch and Veroff 1966 , Atkinson and Birch 1972 , Lawler 1972). These psychologists have suggested that behavioral tendencies (or preference states) are influenced by four different but related components: the incentive component, the expectancy component, the availability component, and the motive component.

The incentive component is defined as the value or the relative importance attached to the consequences of a behavior. For example, one type of user might value solitude more than another. The expectancy component relates to a subjective appraisal (probability) that a particular thing, object, or event will gratify a particular preference to which value is attached. For example, a fisherman might value the solitude of a particular stream very highly but realizes that the stream is used by more canoeists than he prefers. Although he would expect to realize less solitude on his preferred stream than from an alternative stream, he might still go to the more congested area because of other constraints. This leads us to the availability component, which is articulated as the perceived constraints on one's ability to pursue alternative preference states. These constraints deal with time, income, skill level, physical ability, or the supply of recreation opportunities. The final component, or motive, identifies the influence of one's personality dispositions on behavioral tendencies. For example, a highly anxious person might have a different preference for risky recreation activities than a less anxious person, or an introvert might have a different preference than an extrovert regarding social settings in a recreation environment.

Knowledge of the four factors that influence behavioral tendencies can help us define our preference variables better in river recreation research. For example, it is important (particularly for some activities) not to confuse expectations with values--they differ.[1] If the research is designed to quantify expectations, then its focus should not be on values and vice-versa. Also, even though past satisfaction will affect the incentive or value component of preferences, it should be recognized that observed or self-reported levels of satisfaction are not always the same as preference, especially if *preferred types of satisfactions* are not being studied. One can be recreating in a nonpreferred area and be satisfied, but have a strong preference for an alternative area if conditions were such that the alternative were a real choice. Preferences and perceived satisfactions frequently do agree across large numbers of users and over time, else the users would leave the market for those particular areas. Nevertheless, one must be careful when interpreting information on satisfaction levels. Such information might or might not reflect preferences.

Finally, in this section, the problem of measuring latent preferences should be mentioned. Economists talk of revealed and unrevealed demand, with revealed demands being those that can be observed through behaviors such as the paying of a price. Recreation planners have called the unrevealed demands "latent demands." In the public sector, especially, the unrevealed preferences or demands are a relevant concern because these nonusers are paying their prices through taxation. If

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1 Economists and other decision theorists have long separated expectations and values (or utility) when discussing decision processes under conditions of risk (or limited information). Their concept of "expected utility" is well documented (Luce and Raiffa 1957, Von Neumann and Morgenstern 1947).

erences are equated with satisfactions ith revealed demands, these latent de- s have been ignored. Admittedly, these nt demands are difficult to quantify, that is no reason to forget about them.

SPECIFYING TYPES OF PREFERENCES

The previous discussion emphasized the to specify what dimensions of a pref- ce are to be studied. Equally impor- is the need to define precisely what s of preferences are to be studied and *general or specific* the preferences are. example, are the preferences: (1) rather d (or general) and define desires for r-related recreation activity opportun- s; (2) more specific, such as for the ibutes (characteristics or features) of physical setting of a river, of its so- setting, or of management actions that ne a quality activity opportunity in the s of the users; or (3) quite specific respect to well defined types of satis- g experiences that are both expected and red? It is difficult to study all of e or other preferences in one study with- overloading the respondents, the research et, or the researcher!

The specificity needed in preference ies raises challenges to the researcher. he face of limited information on most r users, it is not easy to decide which of preference information is most im- ant. Also, gaining the needed specific- requires a good acquaintance with the ry and methods of the social and beha- al sciences. Finally, a part of the ledge needed to gain the specificity is found in "books," but comes only from riences based on trial and error at- ts; the state of the art is still ing.

SUMMARY AND RECOMMENDATIONS

Research on the preferences of river eationists is complex for several rea- . Seven problem areas identified in paper were:

1. Selecting variables to be included in research designs.
2. Deciding which research approach is the most appropriate for measuring the selected variables.
3. Designing samples and implementing field designs.
4. Collecting preference-related information in the field.
5. Understanding adequately the dynamics of preference formation.
6. Defining precisely what is meant by the word preference.
7. Specifying the type of preference that is to be studied.

Although our discussion of each problem area indicated that there are no easy solutions, we *can* offer a few suggestions or recommendations.

Common to our discussion of each problem was the idea that great care must be taken to define variables precisely when designing studies. In particular, we recommend that the specific types of preferences studied be clearly defined. Along that line of thought we urge for a greater separation of: (1) expectations (which are subjective "probability" estimates that certain values will be realized); (2) incentive values (or the importance attached to particular consequences of recreation behavior); and (3) specific satisfactions (which are the pleasurable experiences that occur *after* revealed preferences have been reflected by paying a price, travelling certain distances, or allocating other resources, such as time, to a particular recreational engagement). By clarifying our variables better, research will obtain more useful information on what is expected and valued, and we will learn more about instances when preferences and actual satisfactions do not agree. Also, through greater specificity of our variables and a clear stratification of preferences by different types of users, environments, and uses, we will be better prepared to determine which types of river-related recreation opportunities should be provided for whom, where, when, by whom, in what amount, and at what price. And in the process, we will achieve a better standardization of measures and variables, which will enhance our ability to make comparisons across different studies.

In addition to care in research designs, good understanding of the theory and methods from the social and behavioral sciences seems necessary for recreation preference studies. Efforts by researchers in the social and behavioral sciences are encouraging in that they reflect increasing agreement about user preferences and behavior. Yet, we need additional cross-checking studies based on

different procedures and more replications of particular designs to see if results are consistent over time and space. Also, the growing practice of researchers to send preliminary drafts of research proposals and manuscripts to peers and managers for review helps solve problems through sharing of knowledge and experiences. Finally, as a recommendation, we suggest that all researchers work closely with local managers in all steps of the research process, including application of the results.

In a nutshell, our recommendations are for: greater care in research designs; a better understanding of the social and behavioral sciences by both researchers and managers; more studies using alternative procedures as cross-checks; more replications of studies in time and space; greater use of peer and manager review of research proposals and manuscripts; and close cooperation between researchers and managers, from hypothesis formation to application of the results.

METHODS USED FOR EVALUATING RECREATIONAL RIVERS IN CANADA

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ABSTRACT.--Reviews techniques for describing and evaluating recreational rivers in Canada. It considers methods developed and/or tested in Canada, and methods developed elsewhere that have been applied in Canada.

Most usable methods for evaluating eation resources have been developed e about 1955. Searth (1970) reviewed of these methods developed in America Canada to 1970, and did not report any ods published in Canada before 1961. following reviews methods developed in da since then to describe and evaluate eational rivers.

EARLY EFFORTS

In a report to Resources for Tomorrow ference, Baker (1961) presented a rehensive overview of government activs related to the provision of opportunities outdoor recreation, and suggested a nationprogram for inventory of recreation resources. id not discuss recreational use of rivers, did not identify specific needs for inven and evaluation of recreational rivers. 963, Baker prepared a report on recreation urces of Manitoba (Committee on Manitoba's omic Future). Rivers were considered al entirely in terms of opportunities for ing and waterfowl hunting. The Resources Tomorrow Conference led to the Canada Inventory program, which included an ntory of recreation resources. Four uation methods were produced in connec with the Canada Land Inventory program.

Method of W. M. Baker

W. M. Baker (1964) proposed a method ecreational classification consisting wo parts: (1) shorelands of lakes (and e rivers) and (2) uplands. The methods ested for shorelands produced detailed riptions of the foreshore, beach, and shore which would be useful for site planning for such uses as swimming beaches, campsites, and cottage areas. The method for uplands consisted largely of classifications of topography and landforms. It did not include a classification of water courses. There was no method for recreational evaluation of rivers.

Method of Hart and Graham

The method of Hart and Graham consisted of three major parts: (1) delineation of "texture regions", based on local relief, landforms, drainage, and other criteria; (2) mapping of physical limitations to recreational uses; and (3) classification of the general capability for recreation, using five quality classes (Acres Company 1965). The delineation of "texture regions" was of no value for river recreation. Of the 10 "limitations to recreation", the following could be related to river recreation: water deficit, inundation or overflow, monotony or lack of contrast in landscape, volume of water, shoreline of water, shoreline quality, and water quality. These limitations were considered in some detail. The final evaluation of recreation potential was made in terms of a variable mix of recreation activities appropriate to an area. Rivers were not evaluated separately, but as contributing to the quality of areas in which they were found.

Canada Land Inventory Method

A method originally proposed by C. S. Brown was selected for use in the recreation sector of the Canada Land Inventory (CLI) (Canada Land Inventory 1967). This was essentially a mapping system, and the map

was the only product. In terms of the evaluation of rivers for recreation, the most distinctive feature of the CLI method was that water courses and water bodies were not evaluated and mapped directly for their recreation potential: "The recreational value of the water body accrues to the adjoining shores".

The CLI method started with the division of nonwater areas into "land units", based largely on physical criteria but also on their value for recreation. The next step was to assign to each "land unit" from one to three "recreation features"; the latter were defined as "an aspect of a land unit providing opportunity for recreation" (p.5). Twenty-five "recreation features" were used:

Angling
Beach
Canoe Tripping
Deep Inshore Water
Vegetation
Waterfalls and Rapids
Glacier
Historic Site
Gathering and Collecting
Organized Camping
Landforms
Small Surface Waters
Lodging
Upland Wildlife
Cultural Landscape Pattern
Topographic Patterns
Rock Formations
Skiing Areas
Thermal Springs
Deep Water Boat Tripping
Viewing
Wetland Wildlife
Miscellaneous
Family Boating
Man-Made Features

A 7-part rating of capability was used, ranging from (1) very high to (7) very low. The basis for capability rating was supposed to be "the quantity of recreation which may be generated and sustained per unit area of land per year under perfect market conditions". The final step was to present the relevant information for each "land unit" by means of letter and number symbols.

One of the most serious defects of the CLI method is that it does not provide an adequate picture of the recreational capability of any region in terms of specific activities or groups of activities (Hamil, 1977). Each small area (land unit) is evaluated in terms of from one to three "recreation features", and the result is a chaotic representation of recreation capability. The problem is aggravated by the fact that water areas are not evaluated directly.

Method of Ontario Recreation Land Inventory

The Ontario Department of Lands and Forests has for many years been engaged in a program of land evaluation, using methods developed by A. H. Hills (1961) (based on earlier work by J. O. Veatch). Climate, slope, soils, moisture relations, and other site factors were used to delineate different levels of land classification, including areas small enough to be used for forestry planning. The Ontario Land Inventory (Ontario Department of Lands and Forests 1968) used a modification of the Canada Land Inventory method, and applied it to areas already delineated by use of the Hills method of site mapping. These smaller units were used in place of the "land units" used in the CLI method.

The concept of "recreation feature" of the CLI method was used with some changes in terminology and definition. The most important difference was (1) detailed mapping of shorelands and (2) separate evaluations of the recreation capability of lakes and large rivers.

The Ontario Recreation Land Inventory used what is probably the most complete available method for describing and evaluating shorelands for potential recreational use. The backshore, shore, and nearshore water of lakes and large rivers were evaluated in detail and the results presented by means of complex consecutive numerical codes. Water bodies, lakes, and large rivers were evaluated for boating and other water-based recreation. Water bodies were normally ranked for boating, viewing, and angling. In addition, some water bodies were ranked for yachting.

DEVELOPMENTS AFTER 1967

Most of the Canadian developments of techniques for analysis of recreational

rs since 1967 have been related to d rivers", or their equivalent. The important of these were the attempts se the methods of L. B. Leopold, by s Canada and the Province of Manitoba. ury and McLeod (1973) developed a useful logy of riverbank landscapes for the between Lake Winnipeg and Hudson Bay. of the other developments have been nements of existing descriptive methods.

Parks Canada Wild Rivers Surveys

According to Juurand (1972a), the da National and Historic Parks Branch idered several possible methods for uating wild rivers: a method developed ater Resource Engineers, Inc. (1970), method of Dearinger (1968), the method orisawa (1971), and the method of L. eopold (1969). The latter method was en.

In the summer of 1971, 16 students ed 3,300 miles on 15 major rivers in Yukon Territory. Two kinds of informa- were produced: unstructured descrip- s and evaluations of the rivers, and old's rating for (46 factors) at loca- s where there were "observable changes" he river or the landscape. In total, sites were chosen for application of the old technique. At each site, one of old's rating forms was filled out. In office, "uniqueness ratios" were calcul- for physical characteristics, water biologic characteristics, human interest acteristics, and all factors. Each of sites was ranked separately for each hese four sets of "uniqueness ratios".

According to the "Summary Report On The Rivers Survey, Yukon Territory, 1971" rand 1972b), problems were encountered nterpreting and using the calculated queness ratings", and the rankings derived them. Experiments were made to try erent ways of combining factors for ulating uniqueness ratios and for ranking s. In addition, "desirability scores" calculated by rating selected factors ays that consistently reflected pre- nces for esthetics and recreational rtunity.

There were serious problems associated the selection of sample sites and the ection of data with Leopold's method, most important of which was interpreting and using "uniqueness ratios" (Juurand 1972a). In spite of these unresolved problems, it was recommended to continue using the Leopold method. A revised version of the method was applied in 1972 and 1973.

The kind of information produced by the wild river surveys of Parks Canada in years after 1971 is shown in, "Description and Analysis of Scenic Resources Along the Churchill, Sturgeon, Weir and Clearwater Rivers (Juurand 1974). This report begins with a short verbal description of stretches of each river. The more technical part of the inventory is based on the revised method used in 1972 and 1973. The river was divided into sections, each designated by a number. These sections were from 25 to more than 100 miles long. They contained one to more than six survey sites. At each site, a rating form was completed, and the following information was used to rate the scenery for the section: water pattern, ratio of river width to valley width, ratio of highest visible point to valley width, vertical view confinement, sample type (reason for choice of campsite), crew rating of preference or quality, miles to next site. "Water pattern" included smooth, surges, waterfall, and rapids. Several other criteria and some simple statistical procedures were also used.

Although the Wild Rivers Surveys of Parks Canada used forms based on L. B. Leopold's technique in 1971, 1972, and 1973, most of the recent reports of results of these studies have been descriptive, and have not included any statistical analysis of data.

In 1974, Parks Canada began to issue illustrated guides to selected Wild Rivers in different parts of Canada. Thus far river guides have been prepared for 10 areas: Alberta, Saskatchewan, Central British Columbia, Northwest Mountains, Yukon Territory, The Barren Lands, The James Bay/Hudson Bay Region, Southwestern Quebec and Eastern Ontario, Quebec North Shore, Labrador, and Newfoundland. These guides are essentially trip descriptions for canoeists for selected rivers and are similar to trip descriptions by many private persons and clubs; they use no distinctive techniques of analysis or presentation.

Juurand, Guzelimian, and Beaman (1974) used some of the data produced in the 1972 Wild River Survey in an elaborate statistical analysis. The 1972 Wild Rivers survey used a modified version of the inventory form used by Leopold. For each site surveyed, a form was completed that listed a number of characteristics of water, banks, vegetation, and other phenomena. The authors used three methods of statistical analysis (linear regression analysis, analysis of variance, and automatic interaction detector model) to extract from the completed forms some information on the relation between the overall judgment of site quality and the individual site factors for which information was collected.

Most of this large report is concerned with the technical details of the three types of analysis used, and discussion of the findings. The authors concluded that the Automatic Interaction Detector (AID) model provides a better analysis of this kind of data than does either the linear regression analysis or analysis of variance. They also claim that the AID model has wide potential application in environmental research.

The 1972 Wild Rivers Study was not designed to investigate how canoeists evaluated river sites. Therefore, the information that was collected at each site was not designed to provide an adequate investigation of this question. In addition, there appear to have been problems of variability in data collection due to incomplete standardization of definitions and procedures. Different results likely would have been found if the initial data collection had been designed specifically to answer the question of how recreational canoeists evaluate a river. Therefore, the results of this study may be considered as indicative, not definitive.

Method of Peter Jacobs

Peter Jacobs (1973), a landscape architect, proposed to Parks Canada a method for evaluating routeways, and applied it to the Chambly Canal in Quebec. The actual survey of the Chambly Canal is described in eight pages of text and three maps, and attention will be limited to this part of the report.

Jacobs starts with a description of the "paths" in the study area (following Lynch 1960), and of how they differ in summer and winter. He refers to three types of boundaries--spatial, activity, and time--and gives examples of each in the study area. The effect of these zones and boundaries on the "legibility" and "congruence" of the area is discussed. Examples of "visual cue dominance" include landforms, water form, and build form. This method provides largely an abstract visual analysis of a routeway, and it requires advanced design skills to understand and use this type of information effectively.

Method of G. B. Priddle

Priddle (1974) proposed to Parks Canada a method for evaluating routeways that could be applied to recreational waterways. The introductory discussion proposed the use of five quantitative methods for determining potential of a routeway for special designation: "landscape potential" of the total route, "landscape potential" of each segment, "visual attractiveness" of each segment, "meaning" of each segment, "visual attractiveness" and "meaning" for each segment, considered together. The formula actually given in the later field manual produces an average for the whole route of the quality estimates made by the observers (as a group) for each segment.

The report consists mainly of a proposed "Landscape Field Manual", in four sections. Section 1 concerns the physical mapping and evaluation of routeways. The actual field mapping of routeways emphasizes "the envelope", "visual penetration", and "sites of interest" and seems to use concepts and procedures proposed by Litton in 1968 and 1973. A six-part quality rating is recommended for rating each segment of the route. A set of management prescriptions is then discussed, including screening, thinning, preservation, conservation, and enhancement. Viewpoints would be identified and evaluated, using Litton's 1973 report on *Landscape Control Points* as a guide.

Section 2 is concerned with "user response to routeway landscape". A number of alternative ways of determining 'user response' are mentioned.

Section 3 is concerned with determining effect of traffic composition and ıme on user response to the routeway. s of obtaining this information are ntified and discussed briefly. A stionnaire was used to elicit this type information as well as that required Section 2.

Section 4 is concerned with economic political feasibility. There is a rt discussion of some of the factors that ht affect economic and political sibility. A "priority rating form" eloped by the U.S. Department of Commerce 66) is recommended. The last part of this ort contains specific instructions for rying out many of the steps mentioned the body of the report. Many of the cedural questions arising from the ding of the text are answered in these tructions.

Method of R. A. Hooper

Hooper (1975), reported on tests of eral methods for evaluating waterways canoeing, and recommended one of them. field study was conducted in the Gammon er drainage, and connecting waterways, t of Lake Winnipeg.

Most of this thesis reports the use of ombination of methods to describe and luate the study area for wilderness oeing. A variant of the method of ighead and Craighead (1962) was used estimate the overall recreational "value" part of the area for wild river canoeing. horeline landscape classification, based the classification developed by Newbury McLeod (1973), was also used. There an additional classification of "land- pe features" included water features, reline features, hills visible from the er, and other features near the water. water flow rating system" included four egories of water state (slow or standing, w turbulence, riffles, rapids and chutes), well as the six-part "International te Water Rating System". Portages and ces where canoes had to be moved by ling, lifting, lining, and other means, e also rated. There is considerable rlap and repetition in the phenomena entoried in these different methods.

Taken together, the combination of methods used by Hooper can provide much descriptive information about a recreational waterway. The simple addition and averaging of quality ratings can provide useful summaries of information about selected factors and groups of factors. But the more elaborate numerical procedures proposed by Hooper do not produce useful information, and are probably technically invalid. The initial objective of developing accurate numerical evaluations of recreational potential and scenic quality of waterways was not met. None of the tests reported in this thesis can be considered conclusive, except perhaps for the test of the utility of the Leopold method, because of the failure to use systematic testing procedures.

Prairie-Badlands Inventory Method of Patricia L. Olson

Patricia L. Olson (1976) reported a study of the scenic and recreational resources of the Milk River Canyon in south-east Alberta. She tested the methods of L. B. Leopold (1968), Parks Canada Wild Rivers, (Juurand 1972a), and Morisawa (1971). These were judged not to provide satisfactory results and an alternative method was proposed.

The Prairie-Badlands Inventory Method of Olson is applied to the visual corridor along the river. It consists of four parts: (1) scenic inventory, (2) feature inventory, (3) hydrologic inventory, and (4) shoreline typology.

The "scenic inventory" used, for evaluation, the "characteristic landscape", variety and contrast in the landscape, and visual distance zones, taken from USDA Forest Service sources (Litton 1968; USDA Forest Service 1973a, 1974c). The "feature inventory" identified the presence of named landscape features occurring in the study area. The "hydrologic inventory" identified selected hydrologic features judged to be important for recreational use or scenic quality, including stream hydrographs. The "shore-line typology" included four shore types.

Three checklists were used to collect the information relevant to each of these classifications. A field evaluation form was used to identify and rate selected land-scape features visible from the river. Three

types of maps were produced: (1) characteristic landscapes and variety classes, viewpoints, and panoramas, (2) landscape features, vegetation patterns, vegetation species, and wildlife habitat; and (3) shoreline units and river features. Olson used numerical quality scalings for selected landscape features. A number of simple statistical techniques were used to summarize and present the data collected.

Apart from the simple (four-part) classification of shore types and the forms used for collecting data, all of the concepts and procedures used by Olson were previously available in published or unpublished sources.

Navigable Mountain River Study of Parks Canada, Western Region

This study of potential recreational rivers in the western National Parks of Canada was begun in 1974 and is scheduled for completion in 1977. An earlier phase of the study identified 11 rivers that were potentially suitable for recreational use: Belly, Waterton, Bow, Kootenay, Vermillion, Kicking Horse, North Saskatchewan, Sunwapta, Athabasca, Miette, and Fiddle. Detailed studies are now being conducted on these rivers to provide the information needed for policy formation and management, as well as information useful to recreational users.

CONCLUSION

The methods reviewed document the development of methods describing and evaluating recreation currently availabl in Canada. Although many of these methods are not widely known, they nevertheless represent the current state of the art in the few government agencies involved in current planning for the future use of recreational rivers. Taken together, these methods include a number of procedures that identify, describe, and evaluate those phenomena most important for the visual experiences associated with recreational boating. The evaluation of opportunities for recreational boating activities is not as well developed, and does not seem to have advanced much beyond techniques available in 1962. The persistence of attempts to use the method of L. B. Leopold in spite of its many demonstrated defects, is one of the most interesting features in this historical process. Another interesti development is the apparent decline in atte to use elaborate quantitative methods, and the apparent increasing use of simple ratin procedures. There has also been an apparen increase in the collection of descriptive information about the visual and activity corridors adjacent to rivers.

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RECREATIONAL USAGE AND USERS OF RIVERS

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ABSTRACT.--Describes trends in the recreational use of rivers using available participation data and usage information for selected rivers. Identifies patterns of socio-economic, and experiential characteristics of users. Evaluates existing data on river recreation use and users and assesses data needs.

There is little in the way of informa-
n specific to participation in river
reation. The supposedly heavy amount of
eam fishing, river-oriented hunting, and
ting on rivers is obscured by the general-
ivity categories customarily used in most
te and National Surveys of recreation.
eover, in many recreation areas, consid-
ble participation in camping, swimming,
other recreation activities is in fact
sely associated with rivers. Canoeing
ms to be the one activity that is fre-
ntly considered, and is generally, though
exclusively, identified with river recreation.

A cautious inspection of available participation information, however, does provide some important insights into the river recreation scene. First, the proportion of the population who participate in canoeing, and the total number of canoeing occasions have increased substantially in recent years (table 1). Moreover, other indicators of interest or participation also support the conclusion that there is a strong upward trend in river-oriented activities.

Table 1.--*Estimates of interest or participation in river-oriented and river-specific activities*

Indicators	Years for which data have been collected											
	1960	1965	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
embership in organizations												
American Whitewater Affiliation members						1,200		1,700		2,200		2,600
American Whitewater Affiliation clubs						75						150
American Canoe Association members		1,000									5,000	
U.S. Canoe Club members		100									1,700	
ponsored river events												
Entries in the Atlanta Ramblin Raft Race				50				8,000				
Races on Southeastern U.S. rivers			10						33			
Sierra Club River outings					24		20	31	35	36	48	
agazine circulation												
Canoe									5,000			30,000
ational surveys of participation												
Population 12 years and older participating in canoeing (millions)	2.6	4.5						3.0[1]				
Canoeing occasions (millions)	7.8	18.9						18.3[1]				

[1]Summer months only.

Existing data suggest that there are substantial regional and state-to-state variations in interest in river-oriented recreation (table 2). For example, the Northeast and North-central regions of the United States appear to account for almost 70 percent of the total annual canoeing occasions in 1972. But individual states in all sections of the country show both very high participation levels and participation rates in river-oriented activities.

THE RECREATIONAL USE OF RIVERS

There is, at this time, no source of complete or comparable data on the use of specific rivers for recreation. Nonetheless, it is useful to examine those data that are available to assess both what they do tell us and what they do not.

Table 3 summarizes river use data obtained from widely divergent sources, such as managers' memoranda, superintendents' annual reports, theses, unpublished research reports, and the like. Obviously, these are not entirely representative of rivers in the United States, but they do provide some insights into the use picture for a variety of different river recreation situations.

The rapidly rising popularity of river use in the late sixties and early seventies is reflected in the use trends for most of these rivers. Rivers showing the greatest use pressures are nearest large concentrations of population in the mid-West and East and close to the Pacific Coast. Some rivers have experienced relative stability, even some declines, mostly as a direct result of the establishment of use limitation programs of one sort or another.

These figures alone do not tell the complete story of the river use situation. Rivers experience considerable season-to-season variability in use. Holiday weekends such as Memorial Day, the Fourth-of-July, and Labor Day, may account for as much as one-quarter of total annual use on some rivers. Use also responds significantly to both seasonal and daily changes in weather conditions, turbidity, water depth, and velocity.

There are also some fairly predictable weekly and daily rhythms. Weekends account for as much as three-quarters of total weekly use. Most daily use is between 10 a.m. and 3 p.m.

Most rivers experience use differences

Table 2.--*Regional patterns of participation in river-oriented recreation activities*[1]

Activity	Population participating	Participation rates: Occasions per person	Participation rates: Occasions per participant	Total occasions (1,000's)
	Percent	*Number*	*Number*	
Northeast Region canoeing (1972)	3.7		6.2	6,200
New Jersey canoeing (1970)				468
Virginia canoeing (1972)	2	.16		700
Delaware river swimming (1970)	2.9	.11	4.1	1,320
West Virginia canoeing (1975)				1,234
South Region canoeing (1972)	1.9		4.1	3,660
Louisiana canoeing (1974)	7.0	.3		1,039
Florida canoeing (1970)			0.8	
Florida river fishing (1970)			1.54	
Arkansas canoeing (1973)		.04		336
North Carolina canoeing (1972)	4.0	.52		1,331
North Central Region canoeing (1972)	3.6		2.8	6,405
Nebraska stream fishing (1972)	21.0			1,913
South Dakota canoeing (1973)	3.3		4.5	98
Minnesota canoeing (1974)	15.0	.78		2,823
Indiana canoeing (1972)		.39		2,165
Illinois canoeing (1975)				356
Michigan canoeing (1972)	12.0			5,891
West Region (1972)	2.2		3.0	2,380
Wyoming stream or river fishing (1972)	36.0		9.9	1,185
Utah river trips (1972)				64
Utah canoeing/kayaking (1972)				61

[1]U.S. Bureau of Outdoor Recreation, Outdoor Recreation, A Legacy for America, Appendix A (1973), and selected Statewide Outdoor Recreation Comprehensive Plans.

1975)

(In numbers)

River by Region	Visits for years data have been collected[1]										
	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
East											
Allagash River (Maine)		4,141	4,539	3,786	4,820	5,460	6,345	7,814	8,337	7,128	9,447
New River (W. Va.)											6,000
Youghiogheny River (Pa.)						17,000				80,000	
Midwest											
Apple River (Wisc.)											
Buffalo River (Ark.)										15,505	18,748
Crow Wing River (Minn.)		9,700									
Current River, Ozark National Scenic Riverway (Mo-Ark)										150,000	
Eleven Point River (Mo.)											
Little Miami River (Ohio)						14,000					
Pine River (Mich.)		13,000					50,000		64,000		
Upper Iowa River (Iowa)								3,416	4,386		
West											
Colorado River, Cataract Canyon (Utah)					585	889	1,670[2]	2,439	4,422	4,096	17,248
Green River, Desolation Canyon (Utah)						1,600		5,000			23,195
Colorado River, Grand Canyon National Park (Ariz.)	547	1,067	2,099	3,609	6,019	9,935	10,885	16,432[2]	15,219	14,253	113,228
Colorado River, Westwater Canyon, (Colo.-Utah)						318		500			7,677
Green and Yampa Rivers Dinosaur National Monuments (Colo.-Utah)			2,493	3,755	5,740	9,762	14,145	17,159[2]	16,739	12,874	35,156
Rio Grande River, Big Bend National Park (Texas-Mex.)	926	1,540	2,741	2,389	3,996	4,006	4,478	4,421	4,850	6,013	
Rogue River (Oregon)							2,800	4,800	5,885	7,210	28,369
Salmon River, Middle Fork (Idaho)	1,260	1,260	1,299	1,396	1,624	3,028	3,250	3,972	4,372	4,036	25,670
Salmon River, Lower Main (Idaho)									4,003[2]	2,200	2,062
Salmon River, Upper Main (Idaho)									2,593		3,201
Selway River (Idaho)						46	194	406	419	439	1,661
Snake River, Grand Teton National Park (Wyoming)		18,000						71,256	73,885[2]	51,906	
Snake River, Hell's Canyon (Ore.-Idaho)									1,184	1,788	9,285
Stanislaus River (Calif.)										35,000	32,572
South											
Chattooga River (S.C.)						300	700	4,000	10,500	14,500	
Everglades Canoe Trails (Fla.)									4,000	5,000	
Nantahala River (N.C.)								1,000	3,000	4,000	
Okefenokee Canoe Trails (Georgia)							300	500	800	2,000	
Hiawassee						800	1,200		2,000	3,000	

[1] Data from various published and unpublished sources.
[2] Year in which restrictions of some type were instituted.

between segments within them. A large proportion of total use may occur at campgrounds or other point locations along the course of a river. Over the length of most rivers, there is considerable variation in attractiveness for various types of river use.

THE USERS OF RIVERS

Who are the users of rivers? Understandably data dealing with the identity of river users are even more difficult to obtain than are use figures. It is one thing to estimate or even count visitors, but is quite another to identify them and to obtain detailed information about them! Nevertheless, based upon the evidence that is available, it is worth making some tentative observations about the characteristics of these recreationists.

Socio-Economic Characteristics

The National Recreation Survey indicates that canoeists are drawn from somewhat higher income groups than participants in other recreational activities[1] as shown below.

Activity	*Family incomes > $15,000*	*With at least 4 years of college*
	(Proportion of participants)	
Canoeing	28	25
Wilderness camping	23	17
Camping in developed campgrounds	24	23
Fishing	18	14
Hiking	24	26
Outdoor swimming (nonpool)	26	20
Hunting	18	9
Total population	21	12

This applies to river users overall (table 4). Thus, available evidence suggests that canoeists (floaters/rafters) are drawn disproportionately from professional or white-collar segments of the society and that they are highly educated. The inclusion in many of these studies of large numbers of students is significant in its own right, but it also may tend to have a depressing effect upon some of the indicators of socio-economic level.

[1]*Bureau of Outdoor Recreation, 1973.*

Studies have shown, however, that ri fishermen appear to be drawn in greater nu bers from lower-income groups and from no professional and non-technical occupation. Also users of the San Antonio River, in a central-city setting, tend to approximate the characteristics of the population as a whole.

Most studies have revealed that river clientele is drawn disporportionately from younger age groups as shown below.

River	*Total* (Perce
Upper Iowa (Iowa)	
Canoeists/Campers (under 30 years)	76
Fishermen (under 30 years)	53
Apple River (Wisconsin)	
"Tubers" (under 25)	64
Rogue River (Idaho)	
Floaters/Rafters/Canoeists (under 40 years)	74
Pine River (Michigan)	
Canoeists (16-24 years)	50
Eleven Point (Missouri)	
Floaters (under 30 years)	67
St. Joe (Idaho)	
Floaters (17 to 29 years)	34
Au Sable (Michigan)	
Canoeists (under 35 years)	74
Fishermen (under 35 years)	51
Colorado River (Grand Canyon)	
Rafters (under 30 years)	27
Total U.S. population	
Under 25 years	46
Under 35 years	58

Over three-quarters of the canoeist/campers on the Upper Iowa are under 30; almost two-thirds of Apple River (Wisconsin) tubing enthusiasts are under 25. In contrast, youthfulness is not a dominant characteristi on some of the Western white water rivers that require considerable investments in guides and/or equipment. This also applies to fishermen on the Upper Iowa and the Au Sable.

Table 4.--*Socio-economic characteristics of users on rivers for which data are available*

River	Proportion of users: Belonging to families whose head of household has a professional/ technical occupation	With at least 4 years of college	Incomes at $15,000-16,000	Incomes at Over $16,000
	Percent			
Rogue River (Idaho)				
Floaters/canoeists	32	54		
St. Joe River (Idaho)				
Floaters/canoeists	17	27	22	
Au Sable (Michigan)				
Canoeists	16			26
Fishermen	19			24
Residents along river	24			42
Apple River (Wisconsin)				
"Tubers"			43	
Middle Fork, Salmon River				20[1]
Pine River (Michigan)				
Canoeists	23	27	27	
Upper Iowa (Iowa)				
Canoeists/campers	27	40		
Fishermen	5	10		
San Antonio River (Texas)				
All users	12		20	
Colorado River (Grand Canyon)			64	
Total United States population	14	12	21	

[1]All over $50,000.

THE EXPERIENCE FACTOR

One of the most distinctive character-
s of river recreation is the extent to
participants are newcomers to a given
.

River	*No experience*	*No experience on this river*
	(Proportion)	
rado (Grand Canyon)		
r	39	94
tor	61	66
(Michigan)		66
able (Michigan)		
noeists		42
shermen		14
en Point		
oaters/Canoeists	11	60
e (Idaho)		
mercial		52
ncommercial		46
e (Wisconsin)		
ubers"		44
r Iowa (Iowa)		
noeists/Campers	55	76
er Load Country		
lifornia)		55
k National		
nic Waterways		33

Moreover there is evidence that a substantial portion have had no previous river recreation experience. These findings are consistent with the previously described rapid expansion of river recreation activity in the United States. Rivers in the West seem to be especially prone to this observation, but the author was unable to find any studies that reported first-time users accounted for less than one-third of total users except among fishermen on the Au Sable.

EXISTING DATA

Obviously then there are important shortcomings in available information regarding the participation in river-oriented recreation. There are some apparent inconsistencies in the participation data themselves. For example, there are almost as many canoeing occasions estimated for Michigan in 1972 as are indicated for the whole North-Central Region in the same year. However, the fundamental problem with respect to estimating participation levels has to do with the fact that most participation survey data are collected and conveyed in activity categories that are not resource specific, or in this case river-specific.

Thus, existing data probably do not give a satisfactory picture of participation patterns and trends.

The data that are routinely available on the use and users of rivers is also inadequate. It is incomplete in that there is no routine in the collection of use data for *most* rivers, and many of the more significant ones. At best, the data sets are coarse, failing to reflect the temporal and intra-river variability in use. There is also reason to suspect that existing data are not accurate representations of the use of rivers because measurement techniques are insufficient. Moreover, certain river-specific uses, such as stream fishing, as well as those activities taking place in the river corridor, are routinely excluded.

REASONS FOR LACK OF ADEQUATE DATA

Factors that account for the difficulties with respect to river recreation data can be readily identified. First, many rivers are not the responsibility of any agency. At the other end of the spectrum, many rivers come under the supervision of a number of agencies, local, State, and Federal. Cooperation in these latter cases is as difficult to obtain as is leadership and responsibility is in the former.

Even where the responsibility for management is clearcut, and the spirit is willing, there is substantial lack of agreement on what is river use. Some organizations restrict the term "river users" to those who pursue river-specific recreation activities, either in-stream or on-stream. Others take the broader view and include in river use all activities that are associated with the presence of a river, including camping at sites located on a river, or hiking along a trail located along a river.

Lack of agreement regarding what types of data on use and users is needed. Not only is there disagreement between planners and managers as to what is needed, but al there may be disagreements among managers of different types of river resources.

Finally, there appear to be inherent difficulties in measuring and monitoring use of rivers. Typically, rivers have a multiplicity of egress and access points. Rivers extend over considerable distances, often through several administrative jurisdictions. They often exhibit markedly different attractiveness, use, and use-potent characteristics in different sectors.

Data Needs

More and better information is needed in order to more effectively plan and mana rivers for recreation. To understand the potential for future development of river recreation demand, there is an immediate need for participation surveys at both National and State levels. Such surveys must be carefully planned so as to provide useful insights on river-specific activiti There is also an urgent need for more accu rate and detailed estimates of usage on a larger number of rivers. In order to meet this need, there must be improved design of use-monitoring and reporting systems in order to cope with the temporal and intra-river variability in use. Finally, there is a need to obtain detailed data on a mor systematic basis as to the characteristics of users both to supplement participation surveys as well as to gain insights that will allow river managers to more effectiv serve their recreation clientele.

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DOWN BY THE RIVERSIDE: INFORMATIONAL FACTORS IN WATERSCAPE PREFERENCE

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ABSTRACT.--Rivers and riversides by their nature are preferred by people because they often provide both a sense of orderliness and a sense of involvement and mystery. The recreation value of rivers extends far beyond fishermen, boaters, and other traditional users. Even unspectacular rivers provide a source of enjoyment and tranquility for many who use only the riverbank, view the river from afar, or who only know that it is "there" and available. Since these "passive" users experience benefits similar to "active" users, their requirements deserve attention in design and management decisions. Ways must be found to involve "passive" users in decision-making so their diverse needs and concerns will not be overlooked.

Whether it's an ocean, lake, river, eam, or pond, placid or fast-moving, nquil or falling, with trees reflected with rapids, water is a highly prized ment in the landscape. Why? Is it just ractive in a picture on the wall or in "real world" too? And does anyone er than canoeists, fishermen, boaters, other active users really enjoy a river?

The truth is that much of the enjoyment t waterscapes provide is low in action. ntless river users are uncounted nonusers. y are not "in the water" but "at the water". sometimes, they are not even right by the erside, but their enjoyment is no less. is almost a use by proxy--a place to en- for its mere presence, for being there.

The purpose of this paper is to examine the riverscape is the source of so much ssive" use and to consider the implica- ns for designing and managing this prized nic resource. The issues that are raised e are important not only for wild rivers those that have been legislated as "sce- ", but also for the rivers of "everyday ure" (R. Kaplan 1976a)--the unspectacular, e accessible ones to which more citizens e more frequent exposure.

In the recreation literature there seems e a separation between the "environment" vers, in this case) as a resource, on the one hand, and the user of the resource, on the other. Studies of users generally involve counts of a variety of background variables and consideration of their motivations for being there. Studies of the "environment" often entail inventories of the countable objects. An important middleground involves the physical environment as it is seen and experienced by the user. Users are not on the river merely to satisfy specific needs, nor do they necessarily know one inventoried category apart from another. They may not notice particular trees, or even litter, or the fact that the banks are eroded. What does constitute their experience? How can one characterize the types of environments that are sought by different groups or by a given person at different times?

LANDSCAPE ASSESSMENT

Much has been written about scenery as a resource. Many different procedures have been developed to analyze the landscape and to examine aspects that users are likely to prefer. A conference on that subject has led to a useful compendium called LANDSCAPE ASSESSMENT (Zube *et al.* 1975). It is a valuable source of background material and innovative approaches. In addition, Cerny (1974) has thoroughly reviewed the scenic analysis literature and also criticized some of the methods with much insight. Although

neither of these sources is restricted to rivers, they shed light on it indirectly and also include material that focuses on rivers per se (e.g., Leopold's (1969a) often-cited study). Two other sources are Morisawa's (1972) review of the literature, and the Litton *et al.* (1974) overview of waterscapes using the landscape-architectural concepts that Litton had previously developed.

Instead of repeating this wealth of material, I would like to focus on an approach to landscape preference that is oriented to the analysis of the attributes of the physical setting in terms of their usefulness to the human observer (R. Kaplan 1975, S. Kaplan 1975, S. Kaplan and R. Kaplan (1977)). The approach will be described briefly here, showing how it applies to environments in general, and then to rivers in particular.

An Informational Approach to Environmental Preference

Humans are a kind of animal that has a well-developed visual system, that has the capacity for a fairly extensive range, and that is, in certain respects at least, social. Like other animals with these characteristics, humans tend to evaluate the terrain and prefer habitats that are likely to offer safety and the resources they need. They stay near the edge of openings--neither in the middle of the open areas where they can see the situation (and others) well but face the danger of being seen, nor "in the woods" where they might hide well enough but not be able to foresee danger. While this description is obviously metaphoric, the parallels to other species are by no means lacking. And for humans as for other animals, the evaluation of the terrain and potential habitat is essentially unconscious, automatic, and continuous.

Unlike other animals, humans are knowledge-based; knowledge makes it possible for humans to be less restricted with respect to a great diversity of environments, climates, food, and social arrangements. They are not only capable of storing information and using it in distinctly different contexts, but this is their standard operating procedure. Humans are, in short, at their best when they can make sense of a situation, when they can comprehend it and feel comfortable with it.[1]

[1] *The description here is based on a rather extensive and far-reaching theoretical position that receives a fuller discussion by S. Kaplan (1973a, 1973b, 1976b).*

However, the story is more complicate Making sense is important and the inabilit to make sense can be seriously debilitatin But, at the same time, having everything i good shape, comprehendible and in order, i not enough. People readily get restless, bored, and even unappreciative. Besides r quiring coherence and order, people look f excitement; they search for adventure or i volvement. So these dual forces are conti uously at play--the simultaneous needs to comprehend and to be involved.

What does all this have to do with th environment? How can the environment affo opportunities for these "dual forces"? Ce tainly, physical settings where one gets lost easily provide failures as far as "mak sense" is concerned. Whether these settin are the most recently designed, prize-winn office buildings, or urban centers (Lynch 1960), or natural places such as parks or backwoods (R. Kaplan 1976b), the inability to "read" them reduces the effectiveness o the user.

Through a series of studies (e.g., S. Kaplan *et al.* 1972, R. Kaplan 1976a) we hav begun to identify some of the elements that enhance the readability of a natural settin Important among these are clues as to the spaciousness of the place. The farther one can see, the more one can anticipate what i in that setting. However, a treeless, flat expanse continuing apparently endlessly is not nearly as effective in providing such clues as is an expanse with a few trees, or hedgerows, or other elements that help defi the space. When such elements repeat--with a row of trees, for example--they further contribute to the coherence. Ground textur are also very important in providing such depth cues. They not only suggest distance by changes in texture, but also give an indication of how "safe" the place may be.

From some of our studies we have learn that natural settings that are rated as "mo liked" are generally not the ones that migh be called most "natural". While the word "wilderness" may often mean a natural area to a resource manager, for some people the setting may turn out to be a well-landscape park, possibly even with a large area of mowed grass! In fact, the highest preferen ratings seem to be reserved for scenes that include a well-kept, orderly component to them. The fact that such preference does not characterize *all* people is very importa It no doubt distinguishes many a resource manager from the people he serves.

That's only half the picture though. was suggested earlier, "making sense" in of itself is often not enough. The most reciated "orderly" scenes are ones that o permit what we have been calling in- vement. Once again, it is useful to mine the elements that enhance this quality. nes that are low in diversity are less in- ving. A large mowed expanse with three or r trees, or endless cornfields are easy ugh to "read", but they lack complexity, ichness of things to look at. Furthermore, olvement is greatly enhanced when one not comprehend the whole at once, but ses that the opportunity is available. s, a scene that is safe and readable enough re one is currently located, but at the e time invites one to proceed and continue exploration, is particularly engaging. ious elements help extend such invitation. bend in the road, the trail that winds, foliage that obscures--all these increase sense of "mystery". While mystery is by means unique to natural settings, it is h more likely in such contexts and may be important factor in the strong preference natural settings (R. Kaplan 1973, 1977a).

Before extending this analysis to the er setting, two issues should be discussed efly. One is the relation of the factors t have been identified in this framework the qualities landscape architects have n using as design guidelines for a long e. Certainly, there is an overlap be- en the two. After all, many scenic places t are considered as "completely natural" their admirers, have been the products of llful and talented landscape architects. major difference lies in considering the delines from a behavioral perspective and neither pointing to a single all-encom- sing factor on the one hand, nor in issuing less lists of potentially contradictory tors, on the other (S. Kaplan 1976a). In ition, the framework differs from other posed categories in being based on intu- vely reasonable considerations--no trivial ter if one is concerned with their utility.

Secondly, there is the matter of the ture (photo, slide, even painting) as osed to the "real" world. In certain s, this distinction is unhelpful. Much of 's "real" experience is from such simula- ns. Since humans are information-based social in their orientation, much of what y know is transmitted vicariously, or cond-hand", if you will. As such, it makes little sense to have completely different factors that help understand picture preference and "real" world preference. Our needs to make sense and to be engaged in the process of acquiring and using information pertain to all activities. (It is thus hardly surprising to find the empirical literature showing a great similarity between ratings made in the physical environment and those made to pictured material--e.g., Rabinowitz and Coughlin 1970, Shafer and Richards 1974, Levin 1977).

What About The Riverside?

Given that such an informational framework to environmental preference is reasonable and credible, why are waterscapes so exceptionally favored? Does water possess these qualities in greater abundance?

Let's begin with the human characteristic of "making sense" out of a waterscape. The study of residents living along a storm drain (R. Kaplan 1976a) made it quite clear that all waterscapes are not appreciated. The ones that received the lowest ratings--and these were low indeed--had the "river" uncontained, unkempt, and disorderly. Of course such considerations reflect more than the water itself. They incorporate the appearance and conditions of the river bank and the river corridor in general. Furthermore, such reactions were no different for those people who lived very near the pictured locations as opposed to those who had not seen them previously. The scenes that received the highest ratings fit with the previously presented analysis. A sense of orderliness seems to contribute to preference. Rivers can provide such a sense easily since they are, by definition, bounded, and it is this very edge which can help communicate a sense that all is well and in its place.

Furthermore, water can easily contribute to a sense of spaciousness. With the addition of islands, or rocks, or even tree stumps this sense is further enhanced. The water itself provides a continuing, unifying theme to the landscape and one that calls attention to itself. It has a texture that easily sparkles, or reflects images, or ripples with the wind.

And how does water aid in "involving" the river viewer? Certainly, a sense of mystery is easily communicated by rivers and riversides. The suggestion that one can find out more by going on, or changing

one's vantage point, is provided by the many turns and twists in the river's path, by the hints of glittering water through foliage, by the changes in vegetation at the river's edge. Remember, this is an involvement in an informational sense--a subtle invitation to want to explore further or, at least, to let one know that further exploration promises further information.

The river, it turns out, has many qualities that are likely to enhance enjoyment. The water itself provides some. Both its movement and its stillness can command attention[2] and, of course, that it so readily changes from one texture to another accentuates these characteristics. Subtle changes in sunlight, slight breezes or winds, obstacles in the water course all play a role. In addition, a river is not a river if it has no edges and so a sense of spaciousness is enhanced by this boundary. The banks themselves provide further interest and potential diversity in wildlife. River edges, too, have textures that enhance the potential attractiveness of waterscapes.

No wonder the riverside is a place to "lay down (one's) burden", to seek for a tranquil moment, to enjoy in even the most passive fashion. Many of the qualities that make riverscapes sought and appreciated are available by the river's side.

SUMMARY AND IMPLICATIONS

People have many needs; the potential list might seem endless. As an animal that operates by knowledge--rather than by speed or fang and claw--the human has a basic need to comprehend, to make sense of the surroundings. Both specific and general knowledge are important, and essential for untold future circumstances. To make the quest for continued comprehension more likely, it seems adaptive for the human to have another basic need which is to search, to explore, to want to know more.

Environmental configurations can be more or less supportive of these needs. They can be dull, confusing, ambiguous, incoherent; they can be exciting, orderly, rich in variety, and enticing. Both the water itself and the river's banks possess qualities that can meet people's informational needs.

For many the river is a resource to be treasured even from afar. Knowing that it is there, that it is available, constitutes a use-by-proxy. If it were taken away or changed in major ways such "use" would be violated and the loss to these uncounted many would be real indeed. The "passive" uses I have been discussing here cut across the consumptive-nonconsumptive distinction. No question, fishermen and canoeists and many others also derive the pleasures discussed here. The beauty and tranquility afforded by the river is there for all of us, even as we relive our experiences many times over.

In a sense then, the river involves an even greater variety of uses (and users) than are usually considered in managing for multiple use. And the more passive uses that have been discussed here can also be thwarted by the effects of other uses, just as other on-the-river uses have been shown to entail potential conflicts.

As a first step in resolving the problem of such a multitude of "uses", we must be sur that the various kinds of "users" are conside in public involvement--a process that frequer leads to the frustration of all parties concerned. But these are the same people, after all, whom we have characterized as having a basic need to understand, to comprehend their surroundings, and as having a craving to explore and know more. They are rarely afforde opportunities to publicly participate. We all suffer the inability to make sense of proposed solutions and potential changes in most areas outside our own expertise! The public is not incompetent; it is uninformed. Fortunately, there are concrete means for correcting that problem (R. Kaplan 1976a, 1977b, S. Kaplan 1976a). And when it is, it can lead to effective participation and exciting consequences.

Litton *et al.* (1974, p. 259) have emphasized "the need for one specific definitiv esthetic policy for use in appraisal of nativ conditions and of developmental impacts". Ce tainly their analysis is correct that current interpretations of esthetic problems are disparate and uncoordinated. But it must be emphasized that their recommendation is in sharp contrast to the proposal made here. The diversity in environment and population

[2] *The importance of attention as a factor in the strong human preference for natural environments is considered by S. Kaplan (1976c).*

not help but require a diversity of ap-
aches if we are to maximize both impact
satisfaction. A unified, definitive ap-
ach could all too easily undermine im-
tant regional differences as well as the
erful consequences of permitting people
ole in comprehending and influencing their
circumstances.

This does not mean a recommendation for
policy, for doing away with designers,
nners, managers, or any other professional
up. It merely recognizes that diversity
as important a principle in the management
articulation of policy, as it is in the
dscape.

There are important and greatly appreciated uses of the rivers above and beyond those that have received considerable attention. There is beginning to be a conceptual basis for understanding these widespread--though neglected--uses. The implications for design and management are several. On the one hand, there is room for greater appreciation of--as well as understanding of--the scenic factors in such environments. At the same time, there is a pressing need to engage the participation of the many interested individuals whose quiet but often intense concerns have previously been overlooked in the decision-making process.

A BACTERIOLOGICAL ANALYSIS OF PORTABLE TOILET EFFLUENT AT SELECTED BEACHES ALONG THE COLORADO RIVER, GRAND CANYON NATIONAL PARK, ARIZONA

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ABSTRACT.--Portable toilet effluent buried at nine beaches along the Colorado River, Grand Canyon National Park, Arizona, was examined for bacteria. Viable total and fecal coliforms were isolated 84 percent of the time. Organisms migrated up to 8 inches away from the burial sites at 22 percent of the beaches. Coliforms were present throughout the strata to a depth of 2 feet. No direct relation was apparent when comparing percent of soil moisture, percent of coarse sand, and numbers of organisms. As ground temperature dropped during the colder months, a comparable decline occurred in numbers of organisms. As ground temperature increased in the spring, a similar increase in numbers of organisms occurred. A definite public health hazard is seen in the numbers of coliforms and associated pathogens that are capable of surviving from one season to the next. Therefore, the health of the 15,000 individuals who annually make Colorado river trips and camp at such beaches is potentially endangered.

A significant sanitation problem was recognized by Park management and other concerned conservationists during 1970 (Bennette 1973 , Carothers 1974) (table 1). In 1972, between late May and July, 132 of 256 individuals involved in 13 river trips experienced gastrointestinal illnesses. Stool specimens revealed that the probable causitive organism was *Shigella sonnei* (Morbidity and Mortality Weekly report 1972).

Because no common food or water source carriers were identified, the outbreak apparently originated in part from infected boatmen who may have transmitted the illness to passengers through food and water handling and inadequate sanitation. The disease could have spread between river parties using common eating places along the river. Contact spread among the passengers probably accounted for the high attack rate (52 percent).

With the inception of Park regulation in 1972, along with excellent cooperation from the commercial river operators, the beaches improved dramatically. The regulations required commercial river parties, representing 92 percent of the total river users, to either carry portable toilets or use other means for the concentration

able 1.--*Number*[1] *of people running the Colorado River Grand Canyon, Arizona*

Year	Users	Year	Users
1955	70	1966	1,067
1956	55	1967	2,099
1957	135	1968	3,609
1958	80	1969	6,019
1959	120	1970	9,935
1960	205	1971	10,885
1961	255	1972	16,432
1962	372	1973	15,219
1963	[2]6	1974	14,253
1964	[2]38	1975	14,305
1965	547	Total:	95,706

[1]Based on revised figures, March 1976, U.S. Department of Interior, National Park Service, Grand Canyon.

[2]Glen Canyon Dam being filled.

ntainerization) of human waste for ial. The recommendations further stipted that burial should occur in a hole least 2 feet deep, 6 feet above the mal high river fluctuation line, at st 50 feet from the river bank, and at st 200 feet from normal camping areas.

Despite the fact that campsites became aner and more appealing, beneath the ches an ever-increasing potential health ard existed in the form of improperly ied and accumulating human feces.

OBJECTIVES

Based on these and other observations, -month bacteriological study was conted at selected beaches along the orado River to determine: (1) the sence and levels of fecal and total iforms and *Clostridum perfringens* (a re former) in human fecal waste burial es; (2) the survivorship of coliform anisms during a winter period when low peratures prevailed; (3) whether sand strate influenced bacterial decomposin; (4) whether bacteria migrated latery from the burial sites toward the er; and (5) whether a significant public lth problem existed at some beaches ed on the above findings.

METHODS AND MATERIALS

Arrangments were made to accompany two 8-day commercial river parties. The commercial trips were chosen to duplicate actual sanitation practices used by large river parties for disposal of human waste. The boatmen conducted the trips as usual, selecting beaches at their convenience and burying the portable toilet effluent according to normal procedures.

A total of 10 beaches were selected between Lee's Ferry and Diamond Creek, a distance of 227 miles (table 2). The beaches were accessible principally by river boat.

Procedures used in establishing the study were as follows: the boatmen selected the site at which the effluent would be buried. A round, plywood board, 2 feet in diameter, was placed over the site and the outer perimeter of the board marked on the sand. A hole was dug 2-feet wide by 2-feet deep. A wooden stake approximately 2-feet long was centered and driven into the bottom of the hole. The contents of the portable toilet, to which a commercial chemical had been added, was emptied into the hole and covered.

Relocation of the burial sites was facilitated by using the reference markers. A substrate core was taken at each burial site by means of a core sampler. The device, 24 inches long, constructed of galvanized pipe, 2 inches in diameter, was fitted with a stainless steel tip to withstand being hammered into the ground and hitting hard obstacles. A clear plastic core tube was inserted inside and a threaded cap screwed onto the upper end to provide a means for the tube to be hammered.

The device was driven into the substrate at selected places within each effluent site. The round plywood board with holes numbered in a circle around a center hole was used to select the exact spot used each month for taking the core. The center of the board was aligned over the stake and then positioned to a permanent reference point at each beach to avoid taking repetitive samples. Each month a new hole on the board was used.

Additional core samples were taken 8 inches away from the edge of the hole to determine whether the bacteria were mi-

grating toward the river. A control sample was taken at random from each beach. Once the tube was withdrawn, the cover was removed and the inner plastic core tube, containing the actual substrate sample, was extracted. Surface and bottom core temperatures were taken at the time of the coring. Often a chemical dye was seen through the clear plastic tube indicating the presence of buried organic waste.

Ends of the core tube were covered with color-coded caps to ensure that the samples could be tested according to their position in the hole.

Distance between survey beaches ranged from 10.5 to 43.5 miles (table 2), therefore, it was only possible to collect samples from one or two beaches per day, depending upon water conditions of the river.

COLIFORM COUNTS WITHIN BEACH EFFLUENT BURIAL SITES

A total of 61 beach dump site analyses were made. Results of the bacterial examinations (combined total and fecal coliform counts) at all beaches were as follows: 15.8 percent of the samples were negative; 22.3 percent had coliform readings of 1 to 25 colonies per plate; and 61.9 percent had readings of 25+ coliform colonies per plate (table 3). Three beaches, Lava Canyon, Papago, and Deer Creek had viable coliform counts every month.

Table 2.--*Beaches where bacteriological analysis conducted*

Beach	Side of River	River mileage[1]	Distance apart
Boulder Narrows	left	18.5	18.5
Silver Grotto	left	29.0	10.5
Upper Nankoweap	right	52.0	23.0
Lava Canyon	right	65.5	13.5
Papago	left	76.0	10.5
Granite	left	93.0	17.0
Deer Creek	left	136.5	43.5
Shelves	right	151.5	15.0
Mile 173.5 Beach	left	173.5	22.0
Mile 185.5 Beach[2]	right	185.5	12.0

[1]Distance from Lee's Ferry, Arizona, principal launching site for majority of river parties.

[2]Surveyed only once, effluent removed for laboratory experiments.

Table 3.--*Monthly bacteriological results*[1] *at selected beaches, Colorado River, Grand Canyon National Park, Arizona*

Beach	October		November		January		February		March		April		May		Percentage			Tot
	1-25	25+	1-25	25+	1-25	25+	1-25	25+	1-25	25+	1-25	25+	1-25	25+	Neg.	1-25	25+	1-2
Boulder Narrows		+		+		+							+		43	14	43	57
Silver Grotto				+		+		+	+		vandalized				20	20	60	80
Upper Nankoweap		+		+	+							+	+		29	42	29	71
Lava Canyon		+		+	+			+		+		+		+	0	14	86	10
Papago		+	+			+		+		+	+			+	0	29	71	10
Granite		+		+				+		+		+		+	20	0	80	80
Deer Creek		+	+		+			+		+		+		+	0	29	71	10
Shelves			+			+		+		+	+			+	29	42	29	71
173.5	No data			+		+	+		+					+	17	33	50	83
185.5		+	Removed for laboratory analysis												0	0	100	10
No. positive:		7/9	4/9	5/9	3/9	5/9	1/9	6/9	2/9	5/9	2/8	4/8	2/8	6/8	15.8	22.3	61.9	8
Percentage 1-25+:	78		100		89		78		78		75		100					

[1]Total and fecal coliform plate counts/100 ml sample.

Table 4 analyzes the bacteriological ndings from all beaches, by month, by mber of coliform colonies per plate, and the type of coliform present. Fecal coli- rm plates were positive 74 percent of e time, while total coliforms, *E. coli* lonies, were positive 66 percent of the me. The ratio of total to fecal coli- rms in normal water samples, is approx- ately five to one.[1] However, because incubated the total coliforms at a gher temperature than the fecal coli- rms, a lower total coliform count sulted. Bacteriological standards for ality of potable water requires that 95 rcent of all samples be free of total liforms. In this study a significantly gher percent of positive sample occurred, wever, such standards are not applicable der these conditions.

Control core samples were negative for cal and total coliforms.

COMPARISON OF BEACH TEMPERATURES VS. PRESENCE OF COLIFORMS

Surface soil temperatures ranged from °F in October 1975 to 31°F in January 76, while those at the bottom of the le ranged from 80°F in October to 38°F January. The mean surface and bottom mperatures were 60.5°F and 61.4°F, spectively. Bottom temperatures were 1°F warmer than surface temperatures during the period from September 1975 to May 1976 (fig. 1). Although temperatures were at or near freezing at some beaches, vegetative cells were able to survive.

[1]*Personal communication with Mr. Don ical, State Health Laboratory, Flagstaff, izona.*

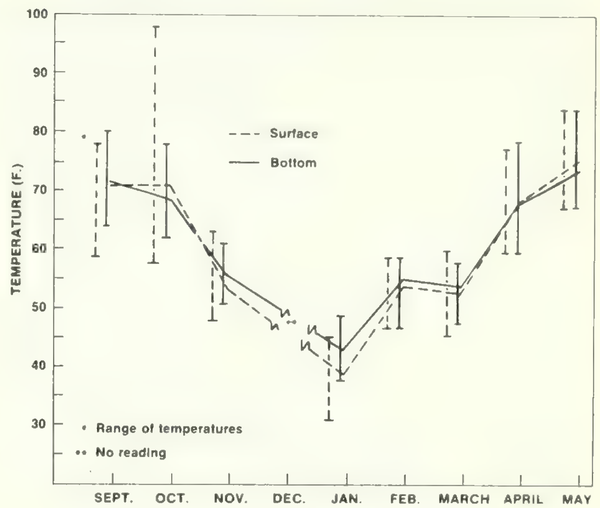

Figure 1.--*Mean soil temperatures at selected Colorado River beaches, Grand Canyon National Park, Arizona, 1975-1976.*

MIGRATION AWAY FROM BURIAL SITES

Substrate samples taken at the edge, and at 8 inches from the edge of the effluent burial sites indicate that some coliform organisms migrated. In October 1975, 61 percent of the beaches showed coliforms in numbers ranging from 1 to 25+

Table 4.--*Bacterial analysis by month at selected beaches, Colorado River, Grand Canyon National Park, Arizona*

	October	November	January[1]	February	March	April[2]	May	Total
Number positive beaches[3]	7/9	9/9	8/9	7/9	7/9	6/8	8/8	52/61
Percent positive beaches	78	100	89	78	78	75	100	85
Percent negative beaches	22	0	11	22	22	25	0	15
Percent positive (1-25 colonies)	0	33	33	0	22	25	25	20
Percent positive (25+ colonies)	78	67	56	78	56	50	75	65
Percent positive (total coliforms)	78	67	67	56	78	13	100	66
Percent positive (fecal coliforms)	78	89	67	78	67	63	75	74

[1]No. survey in December.
[2]One beach site vandalized.
[3]Fecal and/or total coliform.

at the outer edge of the burial sites. Samples in November 1975, taken 8 inches from the edge of the effluent site, indicated migration was occurring at 22 percent of the beaches. In January, 56 percent of the samples taken at the outer edge of the hole were positive for coliform ranging in number from 1 to 25+. It appears that due to low rainfall, little leaching of the bacteria occurs by water movement.

PRESENCE OF COLIFORM IN RELATION TO DEPTH IN BURIAL SITE

In February and March 1976, a single core was taken at each beach to determine whether difference existed in numbers of organisms present in relation to their location within the substrata. From each core, samples were analyzed in the upper, middle, and lower thirds of the hole (table 5). Fifty-six percent of the beaches had coliforms in the upper one-third, 44 percent in the middle, and 72 percent in the lower. This indicates that feces float to the top at the time of burial and that viable coliforms and associated potentially pathogenic bacteria are distributed throughout the site.

CLOSTRIDIUM PERFRINGENS ISOLATIONS

Difficulty was encountered in attempting to isolate *C. perfringens* using the "gas-Pak" incubation system under canyon conditions. *C. limosum*, a normal soil resident often implicated in a variety of animal infections, was identified from cultures taken in December. *C. perfringens*, an organism commonly associated with food borne illnesses as well as being associated with wound complications causing gas gangrene, was isolated in April from several beaches.

Although this study only examined the presence of total and fecal coliforms and *C. perfringens*, other pathogens are surely present. The implication of this is seen in a case of infectious hepatitis, (Morbidity and Mortality Weekly report 1975) that occurred during a commercial Colorado River trip. The individual, who suffered onset and accompanying symptoms of the disease while on the river, probably was excreting virus during the trip and exposed approximately 35 other individuals. Such virus particles can remain viable for months.

ANALYSIS OF BEACH SUBSTRATE

During the February trip, substrate samples taken adjacent to each effluent site were analyzed for soil moisture and sand grain size. In general, soil moisture content and percentage of coarse sand showed little correlation to numbers of coliforms present in the samples. It is recommended that a more complete soil analysis be made to include percentages of clays and other soil types.

Table 5.--*An analysis of where coliform bacteria*[1] *found in relation to depth of effluent at burial sites*

Beach	February Upper	February Middle	February Bottom	March Upper	March Middle	March Bottom
Boulder Narrows						
Silver Grotto	+		+		+	+
Upper Nankoweap						
Lava Canyon		+	+			+
Papago	+	+	+	+		+
Granite	+		+	+	+	+
Deer Creek	+	+	+	+	+	+
Shelves	+	+	+	+	+	+
Mile 173.5	+					+
No. positive:	6/9	4/9	6/9	4/9	4/9	7/9
Percentage:	67	44	67	44	44	78
Totals:	Upper-56%	Middle-44%	Bottom-72%			

[1]Number ranged from 0-25+ colonies per plate/100 ml sample.

CONCLUSIONS AND RECOMMENDATIONS

Coliform bacteria (total and fecal) e found in significant numbers during 3-month study period. A public health ard exists at and near such burial es as seen by the numbers of coliforms lated at surface and near-surface els. Numbers of organisms ranged from to too numerous to count per 100 mls liluted sample. These data reflect a minute portion of the actual pers of coliforms within the substrate. n organisms are able to survive the ors of low winter temperatures. lforms migrated up to 8 inches from burial site. It appears that chemicals ed to the effluent prior to burial are fectual in reducing a significant per of fecal indicating bacteria.

The significance of these findings seen in number of river parties (572) ning the Colorado River in 1975 alone, n an accompanying 15,000 persons, ping an average of 8.8 nights per trip. n such trips, more than 5,000 Park ulation burials occurred, accompanied countless number of nonregulation ials, made at times when portable toi- s were not set up. If river parties l the estimated 200 readily recognized ch sites along the river, a resultant regulation burials would occur per ch per season. However, some beaches eived much greater use due to their ations near popular Canyon attractions. se areas could possibly have 100 or e burials per season. It is at such es that boatmen complain of unearthing vious parties effluent. At other ches, only limited areas for burial st. However, when the course of ast resistance" prevails, burials occur whatever spot is handy or free of lders. At such sites, passengers nowingly sleep and place their per- al gear, risking bacterial contamination.

A significant aspect of this study elated to the impact of the continuing tice of burying human toilet waste at beaches along the Colorado River, Grand Canyon National Park, Arizona.

The following recommendations are presented to assist administrators in establishing river use guidelines to safe- guard the health of future river enthusiasts.

(1) Discontinue the policy directed at commercial river parties specifying that effluent be buried. Instead, require com- mercial boating parties to provide water- tight holding tanks for the disposal of effluent, with the accompanying respon- sibility of disposing of the waste outside the Park. Permit private parties to con- tinue the practice as per current regula- tions. (2) Eliminate small, confined beaches as campsites for all river parties. (3) Establish rustic, pit privies at the larger beaches. (4) Establish Park Service effluent dump stations at a number of locations along the river. (5) Increase river patrols to ensure the presence of Park Service staff at all times during the river running season to assist in the enforcement of regulations.

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BIOLOGICAL APPROACH TO RIVER PLANNING AND MANAGEMENT

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ABSTRACT.--The intent of Wild River legislation was to protect certain rivers for the benefit and enjoyment of present and future generations. To accomplish this goal, river development and management plans must consider: (1) The riverway's ordered nature and inherent limitations; (2) Which specific environments (soils, vegetation) and related variables (aspect, slope) along the river are best able to absorb recreational use; and (3) How much modification (vegetation and soil degradation) of a particular environment will managers accept before they decide to alter or limit use.

What will national recognition of a riverway do to its scenic environment? Will the resource have to be protected from the impact of too many people? Should people using such a high quality natural resource be willing to visit it on nature's terms? If too many use the area and as a result start destroying it, will the public accept a policy that reduces use to ensure perpetuation of the resource?

Such questions have arisen since the Wild and Scenic River Act was passed on October 2, 1968. It designated the 200-mile St. Croix-Namekagon (Minnesota and Wisconsin) and seven other of our nation's rivers and their adjacent environments to be developed for the benefit and enjoyment of present and future generations.

Those involved in river planning have realized that recognizing an area's national significance is one thing; correctly planning and managing it is another. This was the first time our nation had committed itself to preserving several of its rivers; thus planners and administrators were without precedents for guidance.

In early public hearings, one frequent point made was since Wild River planning would be paid for with federal tax dollars it should provide some form of recreation for everyone. In other words, a river plan should attempt to be all things to all people, thereby including such recreational opportunities as motor-boating, canoeing, horseback riding, summer cabins, snowmobiling, auto campgrounds, and motorcycling. Unfortunately, what is not understood by those pursuing this line of reasoning is that the resource--the "setting" where the recreation experience takes place--should not be degraded by planning and development because the presence of the resource's natural qualities was the reason the river was singled out for management in the first place.

Another misunderstanding, this time on the agencies' side, is that it is their responsibility to show the public why certain activities are compatible with an area, and others are not. To do this, the agency must adequately document what the resource was like prior to development and why they developed it where they did. Then after development they must monitor the use of the resource and analyze their data as to whether the planning and management policies are compatible with the resource. Unfortunately, this is not done, so when a new river plan is being discussed at a

ublic meeting and the question is raised, How well has your agency managed its ther Wild Rivers?" the response is sually something like "OK, I guess." his type of response certainly does othing for the credibility of the agency.

To make matters worse a project upervisor tends to get transferred bout every 3 to 4 years. Without good ata for decision-making, the new superisor may have to rely solely on his intuiion, which more often than not means the nnate natural qualities of the resource re degraded. Such a situation results rom the fact that funding is often availble for detailed plans but seldom for onitoring the impact of use or evaluaing the management policies.

WHERE DO YOU START?

The Act emphasized that a river plan ust be compatible with the resource. his implied that data be obtained which ould enable decision-makers to plan for se that did not exceed the carrying apacity and resiliency of the resource. n other words, all planning and manageent decisions must be *biological*; if hey aren't, then alternatives *must* be ooked for.

Within the above ground rules, how does one develop a plan for a Wild River several hundred miles in length when soil and vegetation maps of the area are lacking? Where do you start, what type of data do you need, and where and how do you get it?

It is logical to use a natural land unit, the watershed, as an inventory base, rather than artificial property or political boundaries. The watershed with its soils, vegetation, and wildlife have been evolving together for thousands of years. Both these biotic factors and the six major types of drainage patterns (fig. 1) can be used to make inferences about missing data (Zernitz 1938, Parvis 1947). Thus a resource can be studied with a minimum number of variables.

By delineating the watershed boundary of the designated river on U.S. Geological Survey maps and examining the types of drainage patterns that comprise the drainage network, one can quickly decide whether the watershed is homogeneous or heterogeneous.

If only one drainage pattern is found and the drainage textures are similar, the resource is relatively homogeneous throughout in regard to slope,

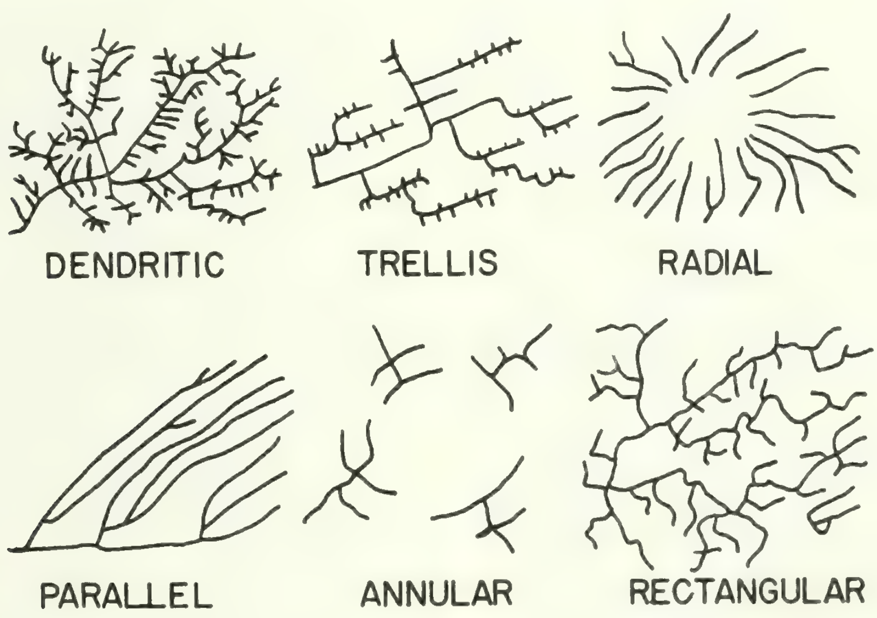


Figure 1.--*Six major types of drainage patterns (Parvis 1947).*

soils, vegetation, and wildlife (Kuska and Lamarra 1973). However, if both the drainage patterns and textures vary (fig. 2), i.e., are heterogeneous, it suggests that the entire area cannot be managed uniformly. Also, the various drainage textures indicate different soil textures and infiltration rates (Morgan 1969), which in turn can have an effect on the type of nutrients that eventually get to the river, thereby affecting the productivity of the river (pounds of fish per acre/year). This could be of major importance if an agency is trying to emphasize fishing in its recreation plan. Such information could also affect a watershed management plan since some soils within the watershed could be so highly erosive that any major disturbance (logging, roadbuilding) could result in high sedimentation rates in the river.

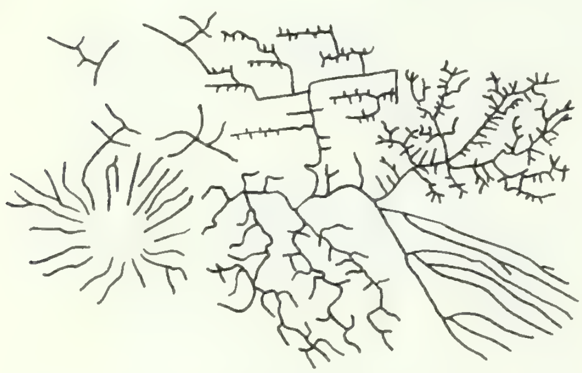


Figure 2.--*Different drainage patterns and drainage textures suggest a heterogeneous soil (Kuska and Lamarra 1973).*

The straightness of the river on U.S.G.S. maps can yield clues as to the homogeneity or heterogeneity of the soil adjacent to the waterway. Rivers flowing through homogeneous unconsolidated material (not bedrock but same material on both sides) are seldom straight for a distance of more than 10 channel widths (Leopold and Davis 1966). Thus, a stream 100 feet wide will be straight no longer than about 1,000 feet if the channel is of the same unconsolidated material. This information will also help the river manager decide early whether a uniform plan can be applied to the entire river, or how many different prescriptions will have to be considered.

RIVER CRITERIA

Once a planner obtains an overview the resource's complexity, he knows *wher* to sample and can start to gather specific resource data. This can save him untold hours of beating the brush, not knowing if he had taken enough data that is "representative" of the project area, or even how many different areas existed. Data on the following criteria should be gathered.

The river environment has five main components (fig. 3). The more ways thes components vary, both individually and i combination with one another, the more enjoyable a trip down a river can be. Cross sections from U.S.G.S. maps can be taken at mile intervals to reveal which stretches of the river have deep or shallow canyon walls, narrow or wide flood plains, and the relative width of the river from one area to another.

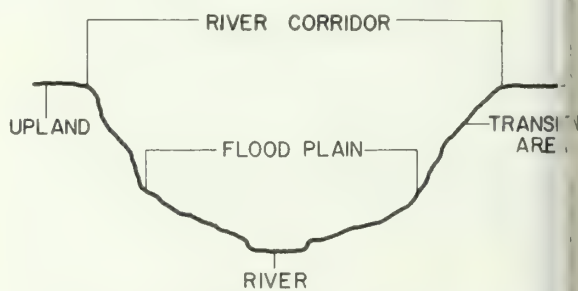


Figure 3.--*Five basic components of a river environment can be identified and evaluated to help determine an area's recreation/development potential (Kuska* et al. *1974).*

Corridor

A narrow corridor helps the river user feel an intimacy with his environment. If the river corridor becomes so wide that a canoeist or kayaker feels as if he were on a lake, the feeling of intimacy is quickly lost. The farther the recreationist is from a riverbank, the less intimate his relation is with plant and animal life, and the more vague points of reference become. The recreationist may feel he is going nowhe thus diminishing the enjoyment of his trip. Also, steep shorelines adjacent t the water will preclude any campground development because constant trampling quickly leads to erosion of the riverban.

Gradient

A graph depicting drop in feet per le will show if the river gradient is milar throughout, or where the fast and ow water will be. If the river has 10- 15-mile stretches of constant gradients, e recreationist will likely run the river gment that he or she can handle. Areas th steep gradients (6 to 8 feet per mile more) should not have developed camp- ounds along the shoreline since the river er is doing all he can to keep afloat such water and is unlikely to attempt ving perpendicular to the current to cure a campspot.

Sinuosity

The amount of bending in a river is lled sinuosity (Chorley 1969). It termines the maximum distance a river er can see another on the river, or at a camper could see another camper wnriver. According to the Wild Rivers t, a riverway should offer a degree of litude. Constantly seeing other river ers on the river means that objective n't being achieved.

Sinuosity, then, could be equated th "visual carrying capacity", a bjective term related to a river user's creation expectations and experience. e more bending (higher sinuosity), the eater a river's visual carrying capacity ig. 4).

Sinuosity is determined by dividing e channel length of the river (along e bends) by the axial distance. A ction of river from 1 to perhaps 4 les long is usually measured: channel ngth might be measured from river mile to river mile 5, and the axial distance traight line) also measured between these o points. This procedure is repeated each mile along the channel (fig. 5). ver sections ranging from 1 to several les in length have to be tried, and one lected which tends to stabilize the lues. The sinuosity values for each ver mile interval are then averaged r each study unit (Kuska *et al.* 1974).

Islands

Islands in a river can increase its sual carrying capacity by decreasing the stance a river user can see downriver

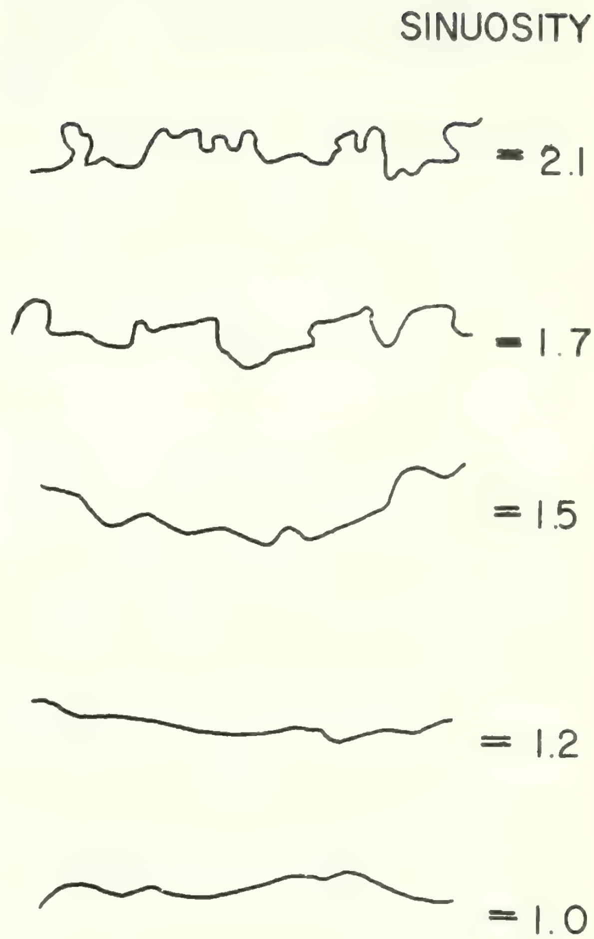


Figure 4.--*Examples of rivers with various sinuosities (Chorley 1969).*

(fig. 6). This data coupled with sinuo- sity, will suggest to a planner the visual capacity of a river. Usually the shorter the distance one can see downriver, the more interesting the river is to travel.

Rapids

Rapids definitely increase a person's interest, which can be instru- mental in determining whether a person will return to the river again. Number of rapids per mile can be counted.

If the river planner plots numerical values for the four previously described topics on four separate vertical axes

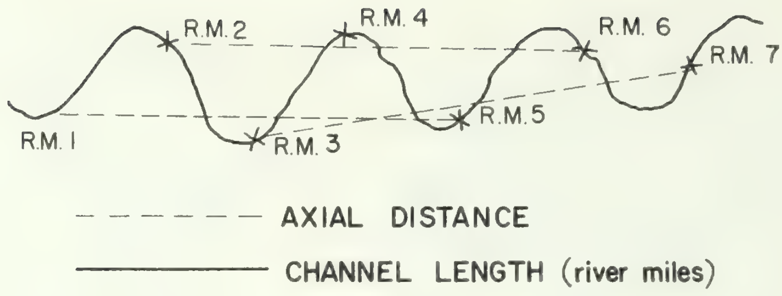


Figure 5.--*Graphic portrayal illustrating how river sinuosity is determined (channel length of river divided by the axial mile length) (Kuska* et al. *1974).*

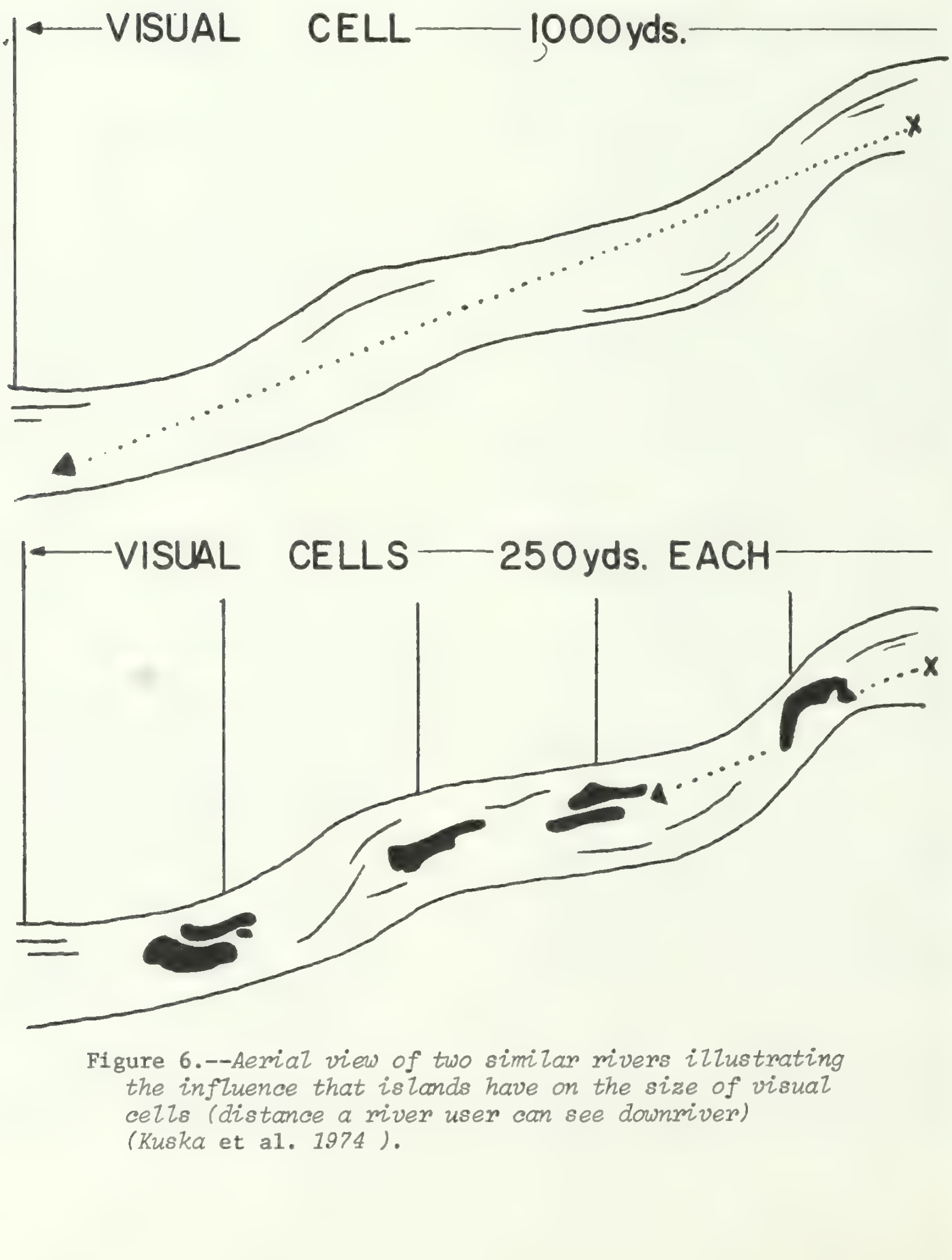


Figure 6.--*Aerial view of two similar rivers illustrating the influence that islands have on the size of visual cells (distance a river user can see downriver) (Kuska* et al. *1974).*

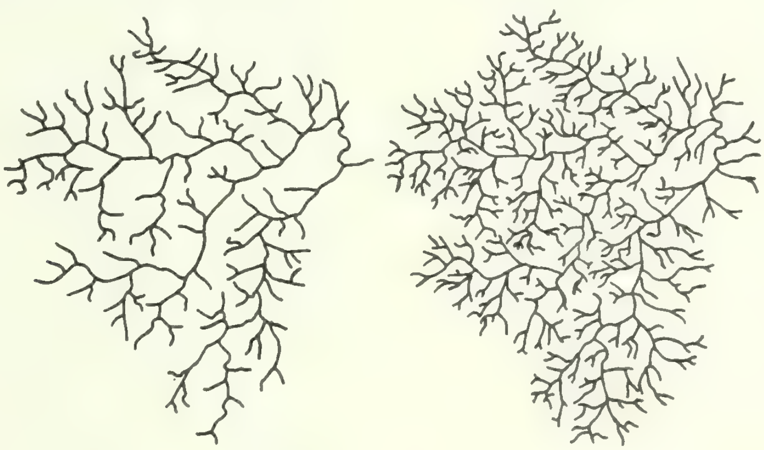
ked one above the other over a common izontal axis showing river miles, he observe where the values for each l to differ, and will be able to allo- e segments to the river. For example, n river mile 0 to 30 the gradient may l5 feet per mile, and from mile 30 75 the gradient may average 1 foot per e. The sinuosity, island, and rapid a will tend to be relatively constant n river mile 0 to 30, but should nge around mile 30 and tend to be stant until about mile 75, then change in to fit the next river segment. s exercise will bring the planner one o closer to understanding the ordered ure of the river and its inherent itations.

FOCUSING ON SOILS, VEGETATION, ASPECT, AND SLOPE

Soil and plant ecology experts would erally agree that campgrounds should kept out of riparian areas. Yet, with designation of national Wild Rivers, nners and managers were just about ced to develop campgrounds in such as. The solution is to find the least sitive parts of riparian areas, and ate the auto ingress, egress, and river r camping there. Unfortunately, re seems to be no clearcut answer as to n which soil texture best withstands reational pressure; Dotzenko *et al.* 967) and Settergren and Cole (1970) nd high clay content best, but Ripley (1962) concluded that sandy areas were better. So many variables must be considered (aspect, slope, climate, intensity and duration of use, etc.), it is doubtful whether any guidelines will ever be applicable nationwide.

How then does one gather data on the soils, vegetation, aspect, and slope of a 200-mile-long river, so that experts familiar with local conditions, can recommend areas that will withstand the recreation impact?

Because soil textures and vegetation are correlated, low-level 35 mm aerial color slides can be used to identify canopy vegetation and thus soil textures. This technique was applied to the 200-mile-long St. Croix-Namekagon River. A slide set with constant overlap was taken from an altitude of about 800 feet at a flying speed of 105 mph. By keying out the vegetation and making field checks, the entire shoreline canopy was identified. By correlating the vegetation with documented soil preferences (Bakuzis and Hansen 1960) and field checking, a general soil texture map was generated. This data can be checked by correlating it with drainage density (miles of stream per square mile of land area). The more coarse material contained in the soil, the smaller the drainage density number; thus a drainage density reading of 0.05 will indicate coarser soil than an area having a reading of 1.85 (fig. 7).



A. B.

Figure 7.--*Differences in drainage density reflect different soil texture; "A" contains coarser material than "B" (Kuska and Lamarra 1973).*

One more check can be made by comparing the sinuosity data with the soil and vegetation data. If the sinuosity information indicates the river is meandering frequently, the inference is that the adjacent shoreline material is unconsolidated and similar on both sides, thus the vegetation should be the same on both sides. If your data does not support these observations, more detailed field work will be required to find out the reason for the discrepancies. Perhaps aspect and/or slope will be found to be the reason why the vegetation is different on the two sides.

On the St. Croix and Namekagon, compilation of the data revealed major soil and vegetation differences between the two Rivers as well as differences between segments of the same river. The Namekagon is bordered by homogeneous sandy soil which tends to be slightly acid, well-drained, and at times droughty. The vegetation, also homogeneous, consists mainly of the pines, namely jack (*Pinus banksiana*), red (*Pinus resinosa*), white (*Pinus strobus*), and northern pin oak (*Quercus ellipsoidales*). The St. Croix River soils were much more diverse, ranging from glacial till deposits to peat and muck soils. This diversity is reflected in the vegetation which consists of American elm (*Ulmus americana*), silver maple (*Acer saccharinum*), river birch (*Betula nigra*), black spruce (*Picea mariana*), alder, and willow. These species are primarily deciduous and usually found in a hydric environment. Such a variety of species suggests a diversity of shoreline environments which would preclude homogeneous development and management for this river.

The above information can be compiled for less than $250 (airplane, film, gas, pilot, etc.) as compared to having the river commercially flown (black and white aerial photos) and hiring a photo interpreter for a cost of at least $3 to $5,000. The lead time for commercial operation could be 6 months to a year. Also, if the person doing the phototaking and interpreting is the principal investigator, he or she is gaining firsthand knowledge about the resource while doing the data collection and interpretive work.

WAS IT THE RIGHT CHOICE?

Vegetation-soil Degradation

An important aspect of any developme[nt] plan is whether it fulfills the managemen[t] objectives. Is the plan retaining the natural quality of the environment--if that's what was intended? In Wild River planning the resource is to be developed for the benefit and enjoyment of present and future generations. Thus, how much modification of a particular environment will a manager accept before he decides to limit the use of an area?

To answer, data *must* have been collected that would attest to the qualit[y] and diversity of the resource *prior* to development. Experts should have been consulted as to which environments (soils[,] vegetation) and related variables (slope, aspect) they felt had the best chance of withstanding the recreation impact, and then the sites had to be monitored.

Planners can help by laying out site[s] so they will be conducive to research projects. For example, one campsite could be developed at a density of 1 unit per acre, another at 3 units per acre, another 5 units per acre, etc. Each of these sites should be as identical as possible (in soils, vegetation, slope, aspect) and then a control area should be established. No camping should be permitted on the control area, so it can be compared with the other sites to discern the effect of camping. The duration, dates, and intensity of use should also be noted; a site may be very durable during the summer months, but if impacted during spring runoff when water tables are high, the site may not be able to recover for the rest of the season.

Aspect should also be closely scrutinized since trampled vegetation is vulnerable to severe heat and drying (Cieslinski and Wagar 1970), and vegetation on the cooler aspects has a higher survival rate than on the warmer ones.

Planners also need "indicator" guidelines which will help them evaluate how well their plans are fulfilling the management objectives. For example, what does it mean if a campsite of such and such density has no tree or shrub regeneration within 100, 200, or 300

et of each campsite? Or if the ground ver for a 10-, 75-, or 200-foot stretch ong the shoreline between the river and mpsites has been reduced by 80 percent-- that degrading the site?

CONCLUSION

Little is presently being done to nd out whether recreational developments on designated Wild Rivers is having a positive or negative effect on the resource. The longer agencies wait to do this the longer planners and managers will be without information from which to make "better" decisions. In addition, the agencies themselves have not defined what they mean by site or resource degradation; thus everyone is looking to someone else for answers. The questions to be asked have not been agreed upon yet.

SIMULATION MODELING AS A TOOL FOR MANAGING RIVER RECREATION

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ABSTRACT.--Accelerating use of free-flowing rivers for recreational floating has led many managers to initiate interim visitor use limits. Ideally managers should know beforehand how use patterns and levels of solitude would be affected when use limits are implemented. We modified the Wilderness Area Simulation Model, developed by Resources for the Future in cooperation with the USDA Forest Service, to predict patterns of river recreation use occurring under a variety of use conditions and tested it on the Green and Yampa Rivers in Dinosaur National Monument for the week of June 23-29, 1975. The "Base Case" simulation and actual patterns of use were compared to test the Simulator's validity and were found to be in close agreement. A variety of experiments, such as changing daily entry rates and opening and closing campgrounds, were simulated.

Recreational use of rivers and streams in the United States has increased dramatically over the past decade. Of particular concern to river managers and many recreation users is the impact of growing use on visitor satisfaction. Research in designated wilderness areas has shown that most visitors prefer few, as opposed to many, encounters with others (Lucas 1964 , Stankey 1973 , Lime 1975b). For river recreation, there has been much less research; but, several studies suggest some users are less tolerant to encounters than others (Roggenbuck 1975 , Pfister and Frenkel 1975 , Solomon and Hansen 1972).

A variety of administrative responses to control or modify river recreation use have been initiated during the last 5 years or so. Daily launch limitations (controlling the number of groups permitted to start per day at each entry point) and party size restrictions are popular measures to control use on about 30 rivers or river segments (table 1). These controls primarily are limited to the West; most are white-water streams, often in canyon settings, and under federal administration; and, such limits have been imposed only within the past several years. Such use controls have been and will continue to be challenged by the recreating public, the commercial outfitting industry, and others through litigation and legislative processes.

SIMULATING RIVER RECREATION USE

The complexities and recent controversies surrounding river recreation issues suggest that the intuitive and subjective approaches often employed in the past to evaluate alternative use management policies may no longer be suitable. More quantitative and objective models of river recreation systems are needed that allow the manager to predict outcomes of alternative use controls prior to their implementation. Such models require managers to identify objectives and to state specifically how much of what kinds of recreation use are acceptable when and where.

Table 1.--*Rivers of the United States with the year daily launch limits and/or party size limits were imposed*

River (State)	Administering Agency	Year Daily Launch Limits Imposed	Year Party Size Limits Imposed
Allagash Wilderness Waterway (Me)	State of Maine	--	1975
Boundary Waters Canoe Area (Mn)[1]	USDA Forest Service	1976	1968
Bruneau (Id)	Bureau of Land Mgmt.	--	1975
Carson, East (Nv)	USDA Forest Service, Bureau of Land Mgmt.	1976	1976
Chattooga (NC, Ga)	USDA Forest Service	1975	1975
Colorado, Cataract Canyon (Ut)	National Park Service	([2])	1972
Colorado, Grand Canyon National Park (Az)	National Park Service	1973	1972
Colorado, Westwater Canyon (Ut)	Bureau of Land Mgmt.	1974	1974
Dolores (Ut)	Bureau of Land Mgmt.	([2])	1975
Green, Desolation Canyon (Ut)	Bureau of Land Mgmt.	--	1974
Green, Dinosaur National Monument (Co, Ut)	National Park Service	([2])	1972
Illinois (Or)	USDA Forest Service	1976	1976
Jarbridge (Id)	Bureau of Land Mgmt.	--	1975
Kern, Lower (Ca)	USDA Forest Service	1976	1976
Kern, Upper (Ca)	USDA Forest Service	([2])	--
Kings (Ca)	USDA Forest Service	1974	1974
Klamath (Ca)	USDA Forest Service	1973	--
Merced (Ca)	Bureau of Land Mgmt.	1976	1976
Owyhee, Lower (Or)	Bureau of Land Mgmt.	--	1975
Owyhee, Upper (Id, Or)	Bureau of Land Mgmt.	--	1975
Rogue (Or)	USDA Forest Service, Bureau of Land Mgmt., Ore. St. Marine Board, Ore. St. Scenic Waterways	1975	1974
Salmon, Lower Main (Id)	Bureau of Land Mgmt.	--	1975
Salmon, Middle Fork (Id)	USDA Forest Service	1972	1972
Salmon, River Canyon (Id)	USDA Forest Service	1973	1973
Salmon, Upper Main (Id)	USDA Forest Service	1972	1972
San Juan (Ut)	Bureau of Land Mgmt.	([2])	1974
Selway (Id)	USDA Forest Service	1974	1974
Snake, Hells Canyon (Id, Or, Wa)	USDA Forest Service, Bureau of Land Mgmt.	--	1975
Snake, Grand Teton National Park (Wy)	National Park Service	1975	1975
Stanislaus (Ca)	Bureau of Land Mgmt.	1974	1974
Tuolumne (Ca)	USDA Forest Service	1973	1973
Youghiogheny (Pa)	Pennsylvania Dept. of Environmental Resources	1973	1973
Yampa, Dinosaur National Monument (Co)	National Park Service	([2])	1972

[1]A million-acre resource with lakes and connecting streams providing the linearity and directional character of a riverine system.

[2]Has seasonal rather than daily launch limits.

Ideally, managers should know how use patterns and levels of solitude would be affected by changes in the amount, distribution, and timing of use before a management policy is implemented. For example, one solution to a suspected overuse situation would be to limit the number of groups permitted to launch from a particular access point. In fact, since 1972 this policy has been implemented by 6 agencies on 19 rivers or river segments (table 1). If such a limit is imposed, some pertinent questions are: How would the river use pattern compare to what it had been before the limit was imposed? How many groups per day, on the average, would any given group expect to encounter? How many groups would camp at each river campsite each night? It would be difficult to answer these and related questions without some means of predicting the behavior of river users.

One approach to evaluating the results of proposed visitor use management policies is to simulate visitor use and behavior with the aid of a high-speed digital computer. Simulation models are simplified representations of real world situations that may provide approximations and insights into the nature of systems that are too complex to be analyzed on a subjective (intuitive) basis.

Resources for the Future, Inc., in cooperation with the USDA Forest Service, has developed such a simulation model--The Wilderness Area Simulation Model. This computerized model can predict levels of congestion that will occur under a variety of use intensities and patterns. It was first used to simulate recreation travel behavior in terrestrial wildland settings (Smith and Krutilla 1976 , Shechter and Lucas, In prep.). Summaries from the model show how many other groups a party will meet or see during the trip (both on the trail and at the campsite), indicate what types of groups are encountered (such as hiker, horseback, small, large, etc.), and will even show the locations within the wilderness where encounters occur.

Through a cooperative study between the North Central Forest Experiment Station and Utah State University, the model was modified for application to river recreation systems. In 1975 it was field tested by the authors on the Green and Yampa Rivers in Dinosaur National Monument.

Knowledge of computer programming or expertise in operating computers is not required to use the model. A users manual (Shechter 1975) is available that describes the type and format of data required to operate the model, the nature of outputs from the model, and other information to aid the user in applying the model to his particular management situation.[1] The model was originally developed using IBM, GPSS-V language and has been modified for use on several other computer systems.

This model is potentially valuable for understanding and contending with the problem of increased river recreation use. It aids managers in assessing a variety of approaches for managing visitor use. Using the model as a tool, managers can make informal judgments regarding appropriate techniques for off-setting undesirable conditions and then evaluate the results. Managers can use it to test proposed use management policies in a faster, more efficient manner than by an on the ground trial-and-error approach spread over several seasons of use.

INFORMATION PRODUCED BY THE MODEL

The simulation model describes what might happen to use patterns on a river under varying use management policies without actually manipulating use and then waiting to see the results. Two general types of output come from the Simulator: (1) information about amounts and patterns of use; and (2) information about the number and location of encounters groups have with each other. Many types of summaries are possible. For example, information by size of group (e.g., small, medium, and large) and types of travel (e.g., privately and commercially outfitted, or kayaks and rafts) could be summarized for:

(1) The number of groups using each entry point;
(2) The number of groups using each river campsite;

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[1]*Available from National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22151. (Manual) Order No. PB 251 635, $12.50 per copy, $2.50 microfiche. (Program) Order No. PB 251 634 (WAUSM) Source Program tape, $ 150.*

(3) The number of groups using a given river segment (e.g., smooth water between rapids and campsites) or a nearby hiking trail,
(4) The number of groups with different trip lengths;
(5) The number of groups entering and leaving the river each day of the simulation period;
(6) The average number of groups encountered per group per day on the river;
(7) The probability of having a group camped nearby on each night of the trip; and
(8) The probability of a group encountering other groups during the day while on the river.

TA NEEDED TO OPERATE THE SIMULATOR

To operate the Simulator, three major s of visitor use information are required the period of time the manager wants to late (often the most heavily used one or weeks in the season).

1. Current river use patterns

   a. Total number of groups launched at each access point by travel mode (e.g., private, commercial) and group size.
   b. Total number of groups launching at each access point by day of the week and by hour of the day--by travel mode and group size.

2. The average time (in minutes) to travel the various segments of the river (such as time between major rapids and between major rapids and campsites).

3. The routes of travel (where groups camp, eat lunch, scout rapids, etc.).

The user of the model can specify the nt of detailed travel behavior to be lated. In the terrestrial field tests, el routes were generalized and consisted ortions of the trail network traversed day and camping locations. Daytime s to rest, eat lunch, and make short trips off the trail were not used in ning routes of travel. In the Yampa Green Rivers field test, travel routes uded detailed daily travel behaviors. Portions of the river traveled were further segmented to include hikes up side canyons of the river, and stops for lunch and to scout rapids. By incorporating this level of specificity into the model, more accurate predictions of use resulted.

When modeling use patterns for either trail or river networks, encounters are defined by the type and size of the party encountered and the conditions under which encounters occur. There are four kinds of encounters. *Campsite encounters* occur when two or more parties occupy the same campground or general camping area. *Meeting encounters* occur when two parties going in the opposite direction pass each other. Meeting encounters seldom occur on the river because most parties travel downstream; however, they can occur off the river when two parties occupy the same general shoreline location to rest, eat lunch, scout rapids, etc., or pass each other while hiking. *Overtaking encounters* occur when one party overtakes another party going in the same direction on the river or on hiking trails. *Visual encounters* occur when a party on the river passes within sight of another party on land or vice versa. Visual encounters occur between parties on the river when they are within sight of one another but do not meet, overtake, or are overtaken.

Although a fair amount of information on visitor use is required as input to the model, most managers probably would not need to start from scratch. Often, much information is already available, especially where use permits are required. Information that is not available (such as travel times on various river segments or routes of travel) can be collected through a special study or during routine work schedules. Also, if no better data exists, it is possible to generate input information for the model based on the manager's best judgment of use conditions.

To determine if the model actually predicts real world use patterns, information from users is needed on the number and location of encounters they have with one another. In this way users of the model can determine the level of confidence to place in the model by comparing actual use conditions with results from the Simulator. The visitor use information collected has other important values such as helping to identify trends in use, pinpointing areas

of high use concentration, and quantifying rates of campsite use.

A FIELD TEST OF THE MODEL

To illustrate how the Simulator works in a river management situation, we tested it on the Green and Yampa Rivers in Dinosaur National Monument (fig. 1). The Monument was chosen as a test location because the problems and issues relating to river recreation management on the Green and Yampa Rivers are broadly representative of those across the Nation. Also, much of the information needed to operate the model was available from National Park Service records.

The river system is intensively used for recreation and managers have become increasingly concerned about the effects of its growing popularity, both on the experiences of people who float the rivers and on the environment. In 1973, an interim seasonal use limit of about 17,000 persons was adopted for both rivers. This figure was based on 1972 use, which had grown rapidly since 1967 (2,500 persons). Since 1973, total use has fluctuated near the limit with the 1976 season recording about 14,000 visits.

River use in Dinosaur National Monument is strictly regulated and supervised. Reservations for trips the following season are accepted beginning December 1. Based on a first-come-first-served procedure, floats are given launching dates and are assigned campsites. There are weekly river patrols and compliance with permit regulations is checked frequently and enforced.

River float trips generally begin in May with a peak during the Memorial Day Holiday. Use remains high through June and July, then gradually declines, and virtually ends by October. In May and June, most use is on the Yampa River, but as the volume of water in the Yampa River drops, the majority of use switches to the Green River generally around July 1. The number of groups launching each day varies considerably. Most groups launch on Thursdays and Saturdays, while Wednesdays and Sundays have the fewest launchings.

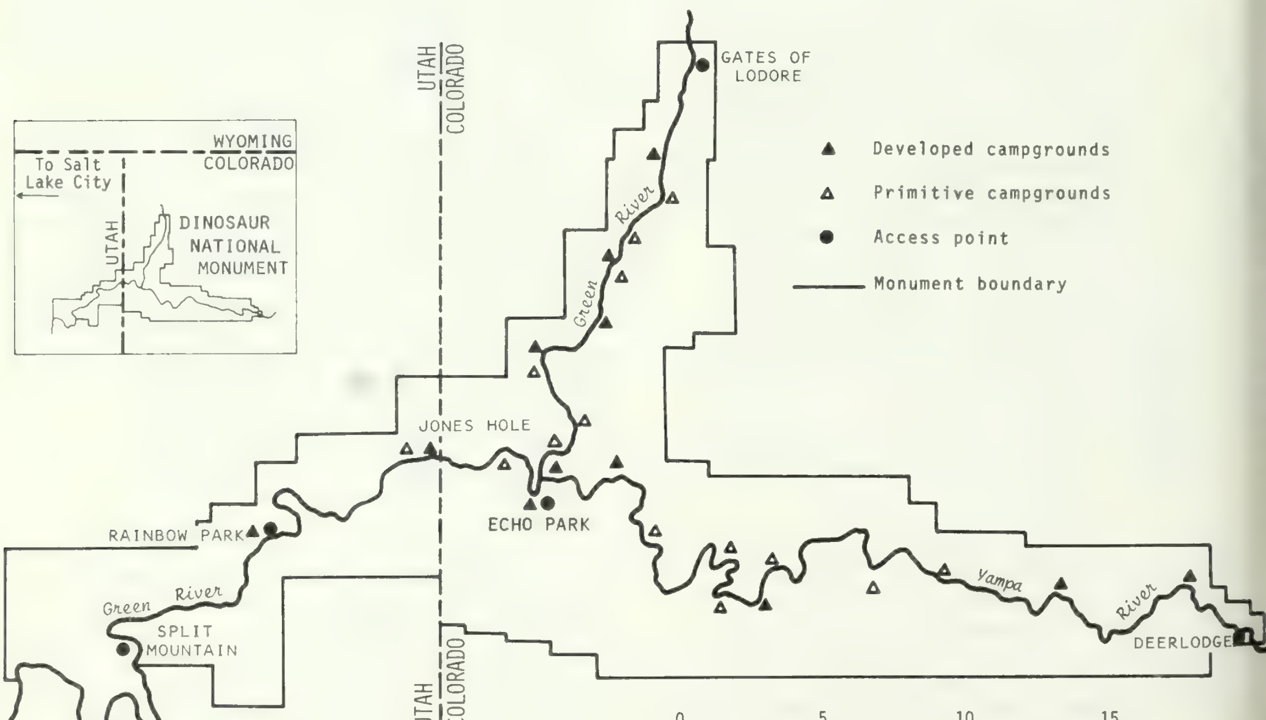

Figure 1.--*Green and Yampa Rivers, Dinosaur National Monument*

In 1975, 12 developed campgrounds (with
ets, tables, and fire grates) and 14
itive campgrounds (no facilities) were
lable along the river for float trip users
. 1). Each developed campground had one
ore developed campsites; primitive camp-
nds accommodate only one party each. All
inaccessible by road and were used
usively by river floaters. Most people
ed at the developed campgrounds but use
ed considerably. For example, during the
od June 9 through July 20 the occupancy
ed from more than 66 percent at the
lar Jones Hole Campground (7 sites) to
than 5 percent at several others. The
itive campgrounds were infrequently
pied; many were not used at all in 1975.

Most of the information needed to operate
Simulator was already available from the
onal Park Service because they routinely
ect it as part of their Special Use Permit
edure. Additional information, such as
el time along river segments, and the
es of travel for individual groups was
ected through a special survey. Sample
ps kept diaries of their travels and
rned them to us following their trip.

Simulating Existing Use

The Simulator was first used to dupli-
or predict the existing river use
erns from June 23 through 29, 1975. This
lation was termed the "Base Case" because
epresented the actual use situation.
ng this period, 44 groups launched from
s of Lodore, Deerlodge, and Rainbow Park.

Once the "Base Case" was simulated, the
were compared with actual knowledge about
patterns for the same period to determine
accurately the model predicted use.
lated data were compared with National
Service records for campground occupancy.
lated data for numbers of encounters on
river (meeting and overtaking encounters)
at campsites were compared with data
ected from visitors who kept a diary.

The model predicted patterns of use well.
lated rates and actual use of campgrounds
elated closely. Simulated and actual
unters (meeting and overtaking) also
highly correlated, although the degree
imilarity was closer for encounters on
river than for camp encounters. The
l overestimated the number of campsite
unters, but this might be attributed to
visitors perceiving fewer groups present at a campground than actually existed.

As expected, the model predicted actual use much better for the entire simulation period than on a day-to-day basis. For example, simulated daily occupancy at campgrounds varied by as much as 50 percent from National Park Service records. This does not mean the model is useless for evaluating the effects of a use management policy on a daily basis, but the model is more useful when interpretations are made using information generated for the entire simulation period.

Simulating Changes in Use

After simulating existing use patterns, use conditions were modified and the Simulator was used to predict resulting use patterns and numbers of encounters that might result if such conditions were implemented by management. Many experimental use patterns were simulated and evaluated--such as increasing use by varying amounts, redistributing daily entry rates between entry points and days of the week, and developing new river campgrounds and eliminating other ones. Some experiments represented use management policies being considered by the National Park Service; others were developed simply to illustrate the effects of fairly extreme modifications in use. Three experiments are briefly summarized below to illustrate how information produced by the model can be presented and what some of the effects of modifying use conditions might be.

Experiment I. Increase the total number of groups taking river trips from 44 to 88 (a 100-percent increase in use). All other conditions remained the same as in the Base Case.

Experiment II. Redistribute daily entry rates so that an equal number of groups entered on each day of the week. All other conditions remained the same as in the Base Case.

Experiment III. Eliminate all primitive campgrounds and add two new developed campgrounds within 2 miles of Jones Hole. Groups who formerly used the primitive campgrounds were assigned to the nearest developed campground; 40 percent of the groups using Jones Hole were equally divided

between the two new campgrounds. All other conditions remained the same as in the Base Case.

In analyzing the results, four questions were asked: (1) What was the percent occupancy at Jones Hole Campground? (2) What was the percent of group-nights (sum of nights camped by all groups) with no encounters? (3) What was the average number of groups encountered (meeting and overtaking) per day, on the river? and (4) What was the percent of group-days (sum of days on the rivers by all groups) with no encounters (meeting and overtaking)?

Several conclusions can be drawn from the results of the three experiments in comparison with the Base Case (table 2).

Experiment I. Increasing use by 100 percent resulted in a proportionate increase in use at all locations. Campground occupancy at Jones Hole approximately doubled while the average number of encounters per group, per day, more than doubled. As a result of other experiments we have conducted and from other field tests (Shechter and Lucas, In prep.) the average number of encounters per group, per day, appears to be a linear function of total use. This means that separate experiments are not required to determine use at a given site and the average number of encounters per group, per day, when comparing the effects of the same experiment with an across-the-board increase or decrease in total use. Because of this relation, the number of experiments required to evaluate a given use policy could be greatly reduced along with a proportionate reduction in computer costs.

Increasing use by 100 percent had on a moderate impact on reducing the probabi of a group camping alone. And, only a th as opposed to about half of the groups in Base Case, met no other parties on the ri during the day.

Experiment II. Equalizing entry rat across days of the week had little influe on either encounters or campground use. might be explained, in part, because the variation in daily entry rates in the Base Case was not extreme, even though there we signficant differences in use between days of the week.

Experiment III. Adding new campgroun and closing others had little overall effe on encounters. As expected, modifying the use at Jones Hole reduced its occupancy. probability of a group camping alone was minimally affected, largely because only a few groups were "transferred" from primiti to developed campgrounds.

DISCUSSION

The Simulator seems particularly usef as an aid to river recreation planning and management because the problem of congesti and overuse is National in scope. Daily launch limits and party size restrictions, frequently based on intuitive decisions, have been widespread--geographically and jurisdictionally (table 1). And, because most of these policies are of recent origi their validity has not been confirmed and remains largely unchallenged, either face-to-face between the administrators and the public or in the courts.

Table 2.--*Selected statistics for the Base Case and three experiments*

Use Patterns	Groups Simulated	Occupancy at: Jones Hole Campground (7 sites)	Group-Nights[1] with no Encounters	Average Encounters[2] Per Group, Per Day	Group-Days[3] with no Encounters[2]
	Number	*Percent*	*Percent*	*Number*	*Percent*
Base Case	44	70	55	1.2	55
Experiment I	88	145	44	2.8	33
Experiment II	44	81	54	1.3	51
Experiment III	44	54	55	1.3	49

[1] Sum of nights camped by all groups.
[2] Meeting and overtaking encounters.
[3] Sum of days on the rivers by all groups.

The Simulator will not make decisions
r managers, tell the manager how to choose
define a given use management policy, or
ll the manager the best way of achieving
desired use policy (reservations, pricing,
ning, altering access, etc.). However,
e model will allow managers to experiment
th various use management policies and to
t an idea of how such policies would affect
ver recreation use patterns so they do not
ve to rely on trial-and-error experiences.
this way managers can test and evaluate
e likely results of use management actions
ickly and inexpensively. Knowing beforehand
e probable outcomes of various policies
ould increase the likelihood that once action
taken to control use, the expected use
nditions will materialize.

The potential for developing use
nagement experiments for simulation is
rtually unlimited. One potentially
eful experiment to reduce encounters
uld be to restrict the time of day parties
ter the river at each access point. On
e Youghiogheny in Pennsylvania and Snake
Grand Teton National Park (table 1),
ch a policy has been implemented and is
der consideration by other river managers
tionwide. The model has the capability
limit the number of parties entering for
y times desired. The results of such
periments should indicate, for example, if
counters were reduced throughout the
periment period or only for the first day
two until a general mixing of use occurred.

It should be understood that the model
s its greatest utility as an aid to river
creation management when the administrator
s managerial control of major river access
ints. This situation exists for all rivers
th daily launch limits (table 1). Altering
e flow of users through access points is
e basic mechanism for controlling use within
e model. All modifications in use--such
types and sizes of groups, time of
unching and dates trips begin, and the
utes of travel taken--are assigned by the
er of the model on an access point basis.
Obviously, then, river managers who control virtually all access to the river (such as in Dinosaur National Monument) would find the model more useful as a management tool than would managers who control only a few access points.

If the model is used to study possible use management policies for a given river setting, and a policy is selected for implementation, it is important to monitor and evaluate the resulting use patterns. Much of the data required would be available as a result of implementing the use management program. Other information, such as numbers and locations of intergroup encounters, would need to be collected. Such a comparison between simulated and actual use conditions would tell the manager the degree to which desired use patterns were achieved, and permit further adjustments if needed.

Part of the rationale for monitoring the effects on use of a use policy would be to determine if the management policy itself altered the subsequent river travel patterns. Studying how users responded to such conditions would provide a basis for developing new experiments and possible implementation. Only under extreme or drastic modifications in use patterns, closure or alteration of campsites and access points, etc., would we expect a significant change in how visitors used the river.

The Simulator has considerable application to planning and management for a wide variety of dispersed recreation activities. The possibilities for imaginative experiments are exciting and challenging. Its application largely is dependent on use situations where recreation users "flow" along specified networks such as trails, highways, or waterway systems. To implement the results of Simulator experiments, managers of such areas must have the authority to enforce limits on the number of users permitted to enter an area through major access points during a specified time.

THE COMPLEX USES OF AN ACCESSIBLE RIVER — THE KETTLE OF MINNESOTA

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ABSTRACT.--Minnesota's Kettle River provides a wide range of recreation attractions from white-water kayaking to canoeing, fishing, and boating within 100 miles of the Minneapolis-St. Paul metropolitan area. Initial results of a study to develop base line visitor data and a means of monitoring use suggest a complex of uses, visitor types, and river conditions. A river of this type must be sensitively managed to meet wild and scenic river objectives.

The Kettle River in Carlton and Pine Counties is Minnesota's first Wild and Scenic River designated under the 1973 legislative act. Situated within 100 miles of the Minneapolis-St. Paul Metropolitan Area, the river is 79 miles long with a total fall of 484 feet. It originates in agricultural land, flows through a sandstone gorge and joins the St. Croix River in a somewhat remote river bottom forest. A central 2-mile rapids (Hell's Gate Rapids) breaks the stream into three use zones. The river offers recreation possibilities ranging from challenging white-water kayaking to canoeing, boating, fishing, swimming, sightseeing, photography, and related activities. All are influenced by fluctuating water levels (fig. 1).

We undertook this study in 1975 and 1976 to test methods for recording river use and use patterns, and to develop a means to measure user preferences that would allow comparisons with other rivers and other times.[1]

[1]*Financial support came from a cooperative-aid grant to the College of Forestry from the USDA Forest Service, North Central Forest Experiment Station, and from McIntire-Stennis Cooperative Forestry Research funds.*

BACKGROUND

Historical records indicate that the Kettle River has been used for boating and fishing by Minnesotans of European origin for over 100 years and prior to that by Ind[ian] people. After the Civil War the river was used extensively for log drives. Sandstone quarrying operations commenced along its banks in the 1880's giving rise to the river towns of Sandstone and Banning. A hydroelectric power dam was put in below Sandstone before 1910. These activities affected river use and the construction of related structures. Apparently, there was some running of the tricky, white-water rapids (Hell's Gate) before 1900. In the 1930-50 period there were small river parks near Askov and east of Hinckley. In recent years the city of Sandstone created a river park at the site of the old quarry.

The river level varies as much as 11 feet at some locations. The best months for river craft are from April through June. However, heavy rains can cause a rise in the river in late summer and a resurgence of canoeing, kayaking, and other uses. Fishing continues at most levels.

The Upper Kettle flows by towns and active farms. Interstate 35 (between Duluth and the Twin Cities) crosses it 31 miles above its confluence with the St. Croix

ver. The lower portion of the river sses through two State parks, a game refuge, State forest, and has limited access. A mbination of existing public ownership, e inherent attractiveness of the Kettle, d perhaps the river's relation to the St. oix (a Federal Wild and Scenic River), couraged interest in its classification a Minnesota Wild and Scenic River under e responsibility of the Department of tural Resources in 1975.

In recent years the Hell's Gate Rapids ove Sandstone have become popular with ite-water canoeists and kayakists from e Twin Cities. Sections of the river ove the Rapids are good for late spring noeing, boating, and fishing. Below Hell's te Rapids the canoeing and boating continue nger, gradually withdrawing to the main ols, as above Sandstone dam, in the late mmer.

RELATED RIVER STUDIES

A great many articles have been written out river use in recent years, particularly nce the passage of the Federal Wild and enic Rivers Act of 1968. River study now s become an important research topic. For r purpose, studies relating to use moni- ring, inventory, and river users were lpful.

Lime (1975a) and others have detailed e need for study of river recreation in e *Naturalist* on River Recreation. In the me magazine Priesnitz (1975) describes e Minnesota Wild and Scenic River System th particular coverage of the attributes d features of the Kettle River. The nnesota Department of Natural Resources NR) has developed a detailed management an for the Kettle River. It includes ps with development locations, management ocedures, and proposals plus coverage on nd acquisition.[2]

PRELIMINARY METHODS AND RESULTS--1975

To obtain some background information the River a check was made of access points and local landowners, including campground and boat rental operations. An overflight of the River was provided on August 6, 1975 by the Department of Natural Resources to count river uses. It was decided to try aerial photograph flights in 1976.

Self-registration stations using cards and boxes (a technique used successfully in the Boundary Waters Canoe Area (BWCA)) were placed at 4 major access points along the river--Banning State Park, Robinson Park (Sandstone), State Highway 48 Bridge, and St. Croix State Park. Respondents were asked to complete a group registration card indicating: date, time of visit, watercraft type (if used), number of people in the group, length of time at river, purpose of trip (check list), and mailing address; comments on the visit were also solicited. Cards then were to be placed in a locked compartment of the registration box.

Unlike the experience with this technique in the BWCA where vandalism was minor and registration was more than 90 percent (Merriam *et al.* 1973), the boxes were badly vandalized and the returns were some- what erratic. (Self-registration could be improved by developing vandal-proof boxes and checking boxes more often. No further use of boxes was made in 1976.) In spite of these limitations the technique did reveal, at relatively low cost, the wide range of activities occurring on the Kettle River (table 1).

For example, responses indicated that 75 percent of the registered parties were engaged in multiple activities involving the River environment, including both the bank and the water. This was confirmed by our river and aerial reconnaissance. For example, rafting and tubing were indicated activities for Banning State Park, where the box was placed at the beginning of Hell's Gate Rapids.

METHODS--1976

The information obtained in 1975 provided the basis for our 1976 tests of observation, questionnaire, interview methods, and aerial reconnaissance. Our investigation focused on the period May 15th through September 15th, the period of heaviest use. During this period we were just as interested in learning

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[2]*Minnesota Department of Natural Re- urces, 1974. A management plan for the ttle River. (Preliminary draft.) 141 p. . Paul, Minnesota.*

Table 1.--*Number of registered parties that engaged in various activities by location, Kettle River, 1975*

Activity[1]	Location: Banning State Park	Robinson Park (Sandstone)	State Hwy. 48 Bridge	St. Croix State Park (Big eddy)	Totals
(Respondents)[2]	(50)	(33)	(25)	(13)	(121)
Fishing	7	9	5	7	28
Picnicking	13	14	1	0	28
Sightseeing	27	21	9	4	61
Photography	15	11	5	0	31
Wildlife Observation	22	13	7	5	47
Canoeing	10	8	7	2	27
Hiking	27	14	4	5	50
Bicycling	3	0	0	0	3
Camping	2	2	1	0	5
Rest and Relaxation	2	0	0	0	2
Rafting	1	0	0	0	1
Tubing	1	0	0	0	1
Rock Climbing	0	1	0	0	1
Beer Drinking	2	0	3	0	5
Scavenging	0	0	1	0	1
Sex	1	0	0	0	1
Prank	5	3	9	0	17

[1]Seventy-five percent of the registrants listed from 2 to 6 activities. Twenty-five percent (30 out of 121) of the respondents listed only one.

[2]Each respondent signifies 1 group of from 1 to 30 people.

when the area *was not* used as we were in when it *was* used, how many used it, their activities, and attitudes.

Observation Methods

An observation method suggested by Burch (1964) was used to obtain data on use at access points (which were also used as interview points). From May 15 through June 30 we counted all river and riverbank users during two randomly selected 3½-hour periods on each sample day (7 a.m. - 9 p.m.). Four of the sample days were weekend days, and four were weekdays, all randomly selected. The access points observed were: Highway 73 south of the town of Kettle River; Willow River (Highway 41), Rutledge (county road); Robinson Park near Sandstone; Highway 48 bridge; Highway 23 near Askov; and Maple Island (St. Croix Park). We were confident that these points accounted for most boat and canoe access to the river (fig. 1).

Access points near the towns of Kettle River and Willow River were abandoned becau[se] of low water by the end of May.

A similar procedure was followed from July 1 to September 15 except that the stud[y] was concentrated below Highway 23, and 4 weekend days and 6 weekdays were randomly selected.

For each access point and time period we recorded the number of people seen, their approximate age, sex, and type of group. Also recorded were their vehicles, equipment, type of watercraft, and their river activiti[es]. Weather and water conditions were also noted.

Interview and Questionnaire

All persons entering or leaving the river at access points were interviewed as to their river use, socio-economic status, knowledge of the Wild and Scenic River, and

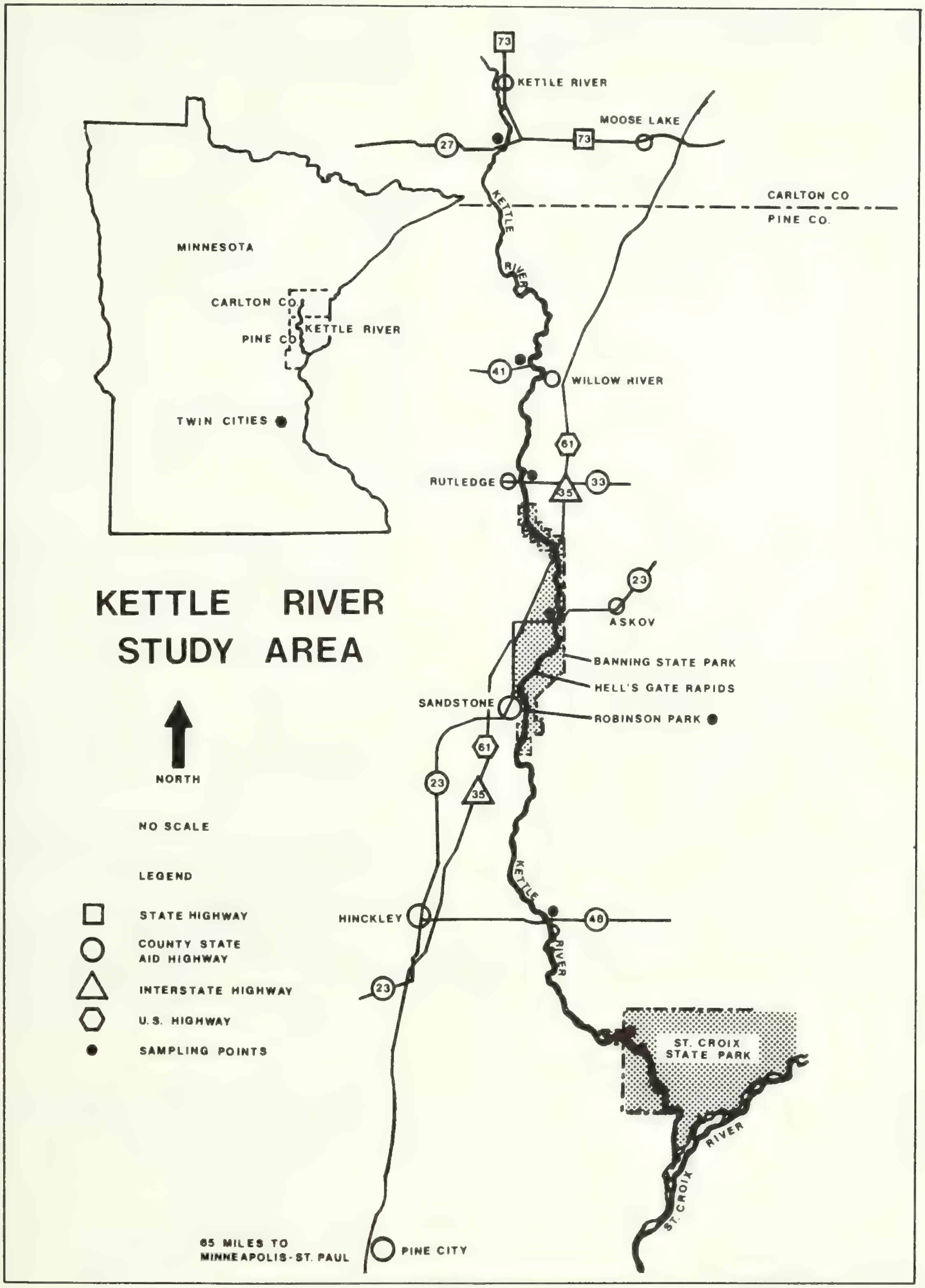

Figure 1.--*Map of Kettle River study area.*

their opinions about Kettle River management alternatives. The interviews were kept brief to avoid inconveniencing the respondents (table 2).

The questionnaires dealt primarily with attitudes on river use and management and trip activities, and took more time to answer. Those interviewed were asked to fill them in and mail them back at the end of their trip. The questionnaire[3] was unique in that it attempted to define preferences in terms of tangible components of the environment rather than vague, subjective descriptions. For example, the respondent was not asked if he was seeking "solitude"; instead he was asked to indicate how desirable it would be to encounter various levels and kinds of use on the river. Hopefully, this approach will reduce the amount of judgmental interpretation in management decisions. The interview and questionnaire were keyed to each other by number. This data is being summarized and evaluated for later reporting.

[3] *Additional information on the use of the River, including the Hell's Gate Rapids, is being obtained by a separate questionnaire sent to the membership of, and in cooperation with, the Minnesota Canoe Association. Data collected is similar to that obtained from other river craft interviewees.*

Between interview periods various sections of the Kettle were run by canoe and other river access locations were observed.

Aerial Reconnaissance

On June 19 and August 28 overflights were made of sections of the River by the Remote Sensing Laboratory plane.[4] Color 35mm photographs were taken to check river use. Photographs were taken at both 4,260 and 2,130 feet altitudes to check resolution differences; researchers on the ground verified photo results. A Cessna 206 aircraft flying at 110 miles per hour, and Ektachrome X film were used in both flights. The primary purpose of the flights was to determine what kind of information could be obtained from aerial photographs. No attempt was made to estimate total seasonal use.

RESULTS--1976

The year 1976 proved to be one of the driest on record in northeastern Minnesota. The Kettle River level dropped by the middle of May and remained low all summer, except

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Table 2.--*Number of interviewees by contact activity and residence*

Type of user	Contact Activity	Residence: Carlton and Pine Counties	Twin Cities Metro Area	Other Minnesota	Wisconsin
River craft	Canoeing	8	12	0	2
	Kayaking	0	2	0	0
	Motor boating	4	2	0	0
	Motor canoeing	0	2	0	0
	Row boating	0	1	0	0
N = 33 Subtotals/(Percent)		12 (36)	19 (58)	0	2 (6)
Bank visitor	Fishing	7	7	5	0
	Hiking	9	6	0	0
	Sightseeing	1	5	1	0
	Swimming	3	2	0	0
	Other[1]	10	3	3	0
N = 62 Subtotals/(Percent)		30 (48)	23 (37)	9 (15)	0
N = 95 Totals		42	42	9	2

[1] Relaxation, lunch, waiting, car washing, education.

r a mild rise in mid-June that made the ll's Gate Rapids attractive to kayakists d most of the River navigable by canoe. e was generally restricted to the lower ver and main pools, such as the pool be- nd the Sandstone Dam that extends 2 miles stream to Robinson Park. River use, par- cularly by kayakists and canoeists, was ght. All State Parks on the River were osed to public use due to fire hazard on e week following the end of our study riod.

Despite these conditions we obtained ch valuable information about the River d its users. Insights were obtained on e role of the Minnesota Department of tural Resources (DNR) in river manage- nt. During the course of our interviews learned much of the local lore, politics, d problems as well as obtaining our study ta.

We interviewed 95 persons in total. the 33 river craft interviewees, 19 8 percent) were from the Twin Cities tropolitan area with 12 (36 percent) om local counties (table 2). On the her hand river bank visitors were more ften locals, 30 out of 62 (48 percent) th 23 (37 percent) from the Twin Cities. noeists and kayakists were younger (79 rcent in the 18-31 year age range) than at and motor users (55 percent in the)-70 age range).

Seventy-nine percent (49) of the con- acted bank users knew of the Kettle River's ild and Scenic River status and most ap- roved of it. Four local people voiced eservations concerning adequate river rotection and displacement by outsiders. n the question of charges to manage the ettle River, 54 percent of all locals olled opposed charges as compared to 15 ercent opposition from other parts of innesota.

Local residents were not always in une with on-the-ground management deci- ions. At the Highway 23 access that is n Banning State Park, a river access canoe ampground had been installed and a road locked by park officials to keep cars out. he local people who had previously used he road for fishing access pulled down he barrier several times.

The aerial photo flights enabled us o count and describe river users at a particular point in time. On the higher altitude photos (4,260 feet) it was possible to identify all river craft by type in the main river channel. People, however, were difficult to count. On the other hand, at the lower altitude (2,130 feet) individ- ual craft, people, inner tubes, vehicles, etc., could be identified. It was also possible to identify canoeists with or without packs and other gear.

In the aerial photos forest vegetation tends to limit counts of shore fishermen and bathers. Probably, there would be better resolution of objects if Kodachrome rather than Ektachrome film was used. Cloud cover, wind and cost would limit the use of aerial photo counting. Interviews, checks, and aerial photos from this study showed that 1976 use was concentrated in river segments with adequate water.

It was interesting to observe the various techniques utilized to overcome the problem of getting people and equipment from one end of a "use unit" to the other. (Hell's Gate Rapids, a use unit used pri- marily by white-water canoeists and kayakers when the River is high enough for passage, separates the upper river and lower river use units, which are generally used by cruising canoeists, boaters, and fisher- men.) In some relatively short stretches, it is possible to simply motor back upstream. This technique permits a party to put in and take out at the same point. It is used primarily by fishermen and is not very popular with canoeists who may be trying to experience more interesting parts of the River and are probably reluc- tant to use motors in any case. One canoe- ist was observed "poling" upstream. This technique may gain in popularity as more people become aware and skilled. Hitch- hiking was also observed.

The authors experimented with a "bicycle shuttle"; i.e., a bicycle was hidden at the lower end of the use unit and used to return for the transport vehicle. This technique is quite efficient when there are only two people and one automobile. These observa- tions suggest that the logistics of shut- tling back and forth may be an important factor affecting use patterns.

The Hell's Gate Area deserves special consideration. This segment is a series of rapids totaling about 2 miles in length and

is very popular with white-water enthusiasts using kayaks and covered canoes. The season is relatively short since this area can only be negotiated when water levels are sufficient, usually in the early spring. It is also possible for the water to be too high and therefore dangerous. During the study period DNR personnel cleared a portage trail around the rapids on the east bank of the River. This facility may have a significant effect on use patterns and may reduce the barrier effect of the rapids; the scenery of this section should also act as an attractant.

The "where" and "when" of use are inextricably related. However, it is useful to abstract the time dimension for the purpose of analysis. Other than extreme cold, water level has the most important effect on use. The canoeability of the Kettle River is extremely sensitive to variations in water level. As water levels go down, people tend to concentrate on the lower sections of the river and there are fewer of them for researchers to contact. Reputation for having an adequate water level is probably as important as actual water itself, and a group is more likely to plan a trip for a stretch of river having a reputation for adequate water level during that period. Canoeists with knowledge of how the river is affected by local rains can take advantage of temporary rises in the water level. A Department of Natural Resources service which gives information via telephone on water levels may influence use.

Other time-related variables, such as rain, hot weather, and insects influence use in a less predictable manner. As expected, we found the weekends to be the principal summer river use periods on the Kettle. It was obvious that the Kettle River is not typically the site of extended summer visits.

From observation and bank interviews in 1976 we found that many local townspeople use the River as a social gathering point for celebrations (e.g., 1976 Quarry Days in Robinson Park), for bank fishing, swimming, and car washing. Some of them frequent particular locations used for years and have never used a canoe or boat. Developments changing these uses may be viewed by some as threats to local life styles. Other conflicts could develop simply because of increased use or because management tended to favor one use over another. If canoeing should increase significantly it may interfere with fishermen, both in boats and on the bank.

DISCUSSION AND IMPLICATIONS

So far our study suggests several things about monitoring river use and visitors--at least on our study river. First of all, to obtain meaningful data, a river study should cover a period of several years so as to avoid unusual conditions like the low water and dry conditions of 1976. Secondly, counting techniques for readily accessible areas should not depend on easily vandalized counters or registration boxes. Aerial photography and aerial counts offer hope to check use patterns. Few people go to the Kettle for just one activity. There are also different use patterns for difficult river segments and seasons of the year.

On the Kettle, and perhaps other rivers there are definitive differences in the use patterns of local people and those of persons from a large metropolitan area. A management agency may want to maintain constant communication with local residents as they implement day to day on-the-ground decisions It probably is not enough to involve them only in the original planning process.

Programs such as Minnesota's "Wild and Scenic Rivers" are very broad in nature. Legislation provides general guidelines, but the management agency must be able to interpret specific needs. Our study has helped to show that rivers have qualities that should be emphasized. Mere designation does not provide the detailed management directives that are necessary, although it is important to remain consistent within the limits of legal authority.

The Kettle River is a good example of a river with unique qualities. It is quite evident that a stereotype "plan" cannot be superimposed on this river. Due consideration must be given to the unique aspects of the river, both physical and social. It will be especially critical to take into account local use of the river and traditionally established uses. We are not suggesting that these be overwhelming determinants for management, but only that

ey must be dealt with in a straightforward nner.

We have also discovered that it is possible to deal with one kind of land river use without taking into account e effects of other uses. The latter may be very subtle and complex. For example, winter use may, at first glance, appear to have little relation to summer use. Yet, winter activities may contribute to a person's overall familiarity with the area and may help to "set the tone" for later use of the area.

AN ATTEMPT TO QUANTIFY THE ESTHETICS OF WILD AND SCENIC RIVERS IN IDAHO[1]

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ABSTRACT.--Describes the procedure used to estimate demand for outdoor recreation on rivers and in development of a Likert-Type Scale to distribute the net resource values estimated in the demand analysis according to perceptions that users indicated as being important to the wild and scenic river experience.

We sought to develop a basis for quantifying recreationist responses to the wild river environments. The quantity of such experiences are affected by many factors: the weather, mood of the individuals involved, time of year, related types of outdoor recreation in which they participated (such as fishing or hunting), type of watercraft used (if a floating experience), type of land transport (hiking, motoring, or horseback experiences), and types of wildlife encountered. Together these are referred to as the esthetic experience.

This definition was further defined to include their perception of natural beauty seen on or near the river. These perceptions change as one moves along a stream. This creates problems because it implies that esthetic perception is a dynamic problem and that a recreationist has certain esthetic expectations when he plans his trip that change during the trip. Thus, any attempt to develop a single valued function to quantify esthetics is not likely to be completely successful. As a result, the numbers in this study are used as indexes of relative esthetic value, not used absolute values.

[1]*Published with approval of the Director, Idaho Agricultural Experiment Station, Agricultural Research Paper No. 7612. This project was partially funded by the Water Resources Research Institute, University of Idaho, Moscow, Idaho, Project No. C3342.*

RELATION BETWEEN ESTHETICS AND OUTDOOR RECREATION

The data used in this study covered three areas on the Salmon River, and the Middle Fork Salmon River, based on a survey done in 1969; and on the St. Joe River and in the Stanley Basin on the Upper Salmon River, based on surveys done in 1971 (fig. 1). We developed outdoor recreation demand models for these areas to provide the basis for valuing outdoor recreation, and hence for esthetics. These models estimated the number of visitor days that would be consumed at alternative costs per visitor day. A visitor day was defined as any portion of a 12-hour period spent recreating in the out-of-doors. Our efforts are directed toward finding a way to allocate value to the esthetic portions of the whole outdoor recreation experience. To establish this relation, we sought to determine the amount of "consumer surplus" involved in the outdoor recreation experience, and then to estimate how much of it was related to esthetics.

Consumer surplus is defined as the difference between total utility and the market value of a good or service. The difference is a surplus of utility that a consumer receives because they get more than they pay for. This occurs because each unit of a good or service that a consumer buys costs only as much as the last unit is worth. And according to the law of diminishing marginal utility, the previously purchased units are worth more than

Figure 1.--*Wild and scenic river system in Idaho.*

those purchased more recently. Thus he obtains a surplus on each of the earlier units purchased.

A graphic example is shown in figure 2. At a price P_1, the total cost (TC) is the area included in OABC, and the consumer surplus is the area included in ALB for the quantity q_1. At the price of P_2, the total cost is the area ODEF and the consumer surplus is the area DLE for the quantity q_2. The gain in utility is represented by the area DABE. At price P_3, the total cost is the area OGHK and the consumer surplus is the area GLH for the quantity q_3. The gain in utility is the area GDEH.

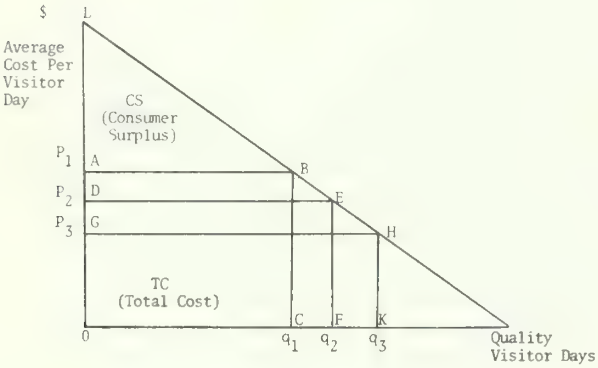

Figure 2.--*Hypothetical demand curve for recreation.*

As consumption increases, the price falls, and each unit costs less. This is the mechanism that creates the consumer surplus.

We used Nawas' (1972) technique to estimate the demand for outdoor recreation. This uses data obtained from recreationists to estimate a demand curve for outdoor recreation. The data gathered consists of user costs that are substituted for price data normally used in market demand studies.

The demand for river related recreation was estimated for the following three general recreation areas in the Salmon River area: (a) the Upper Basin, which was defined as the river between Stanley and Clayton, Idaho; (b) Corn Creek, the river between North Fork, Idaho, and Salmon Falls; and (c) Lower Basin, the river between Salmon Falls and White Bird, Idaho (fig. 1). The Middle Fork of the Salmon River included all of the river downstream from Dagger Falls and all of the St. Joe River. The Stanley Basin included the area above Stanley upstream to the Galena Summit area.

Demand equations shown in the box were estimated for several rivers, all of which have quite different characteristics. The statistics of fit for all the equations are shown in table 1. The Middle Fork of the Salmon River is unique for its whitewater rafting. The Salmon River is noted for its fishing in the upper reaches including the Stanley Basin, and also for its outstanding scenic beauty. The Corn Creek and Lower Basin are noted for steelhead and salmon fishing, jet boating, hunting, and camping resources. The St. Joe River is a canoeing, fishing, camping, and hunting river.

Demand Equations

Stanley Basin, N = 425

1971 $\hat{Y}=40.5505+0.00056X_{1_i}+0.0499X_{2_i}-13.1362X_{3_i}+19.4988X_{4_i}$

(0.00022) (0.0272) (0.9409) (1.3763)

Where $\hat{Y}$=number of visitor days
X_1=total income of person responsible for covering expenses
X_2=total annual paid vacation time for nonretired persons
X_3=total transfer costs per visitor day
X_4=travel time to and from recreation area

St. Joe River, N=109

1971 $\hat{Y}=20.425+0.986X_{1_i}-0.012X_{2_i}+0.34X_{3_i}-5.777X_{4_i}$

(0.3926) (0.0033) (0.0321) (0.5544)

Where $\hat{Y}$=number of visitor days
X_1=travel time to and from river
X_2=miles travelled to and from river
X_3=total cost of trip
X_4=total transfer cost per visitor day

Main Salmon River Areas

1969 1. Upper Basin, N=150
$\hat{Y}=18.6233-0.6675X_{1_i}-0.7084X_{2_i}+0.0002X_{3_i}$

(0.17004) (0.94848) (0.00019)

1969 2. Corn Creek, N=159
$\hat{Y}=19.0331-0.6736X_{1_i}+1.5999X_{2_i}+0.0001X_{3_i}$

(0.13121) (1.18315) (0.00024)

1969 3. Lower Basin, N=304
$\hat{Y}=17.2797-0.4921X_{1_i}-1.2347X_{2_i}+0.0001X_{3_i}$

(0.07474) (0.87836) (0.00017)

Where $\hat{Y}$=number of visitor days
X_1=total transfer costs per visitor day
X_2=education level
X_3=income level

Middle Fork Salmon River, N=218

1969 $\hat{Y}=12.66783-0.07879X_{1_i}+0.30243X_{2_i}-0.00001X_{3_i}$

(0.01625) (0.17429) (0.00003)

Where $\hat{Y}$=number of visitor days
X_1=total transfer cost per visitor day
X_2=education level
X_3=income level

Table 1.--*Statistics of Fit for Outdoor Recreation Demand Equations*

Equations	Date	Linear form				Log form		
		N	R	R^2	F	R	R^2	F
Stanley Basin	1971	425	0.646	0.418	[1]75.4	0.706	0.498	[1]73.50
St. Joe	1971	109	0.768	0.590	[1]37.41	0.805	0.648	[1]47.82
Upper Basin	1969	150	0.324	0.105	[1]11.43	0.694	0.482	[1]45.25
Corn Creek	1969	159	0.402	0.162	[1]16.54	0.808	0.653	[1]97.15
Lower Basin	1969	304	0.368	0.135	[1]13.65	0.764	0.584	[1]140.41
Middle Fork	1969	218	0.351	0.173	[1]3.58	0.641	0.412	[1]49.87

[1]Significant at the 0.001 level.

DEMAND SCHEDULES

Schedules showing how visitor use would change with a change of costs per visitor day are shown in table 2. Obviously, costs would have to increase significantly if use were to be reduced on the Salmon River or on the Middle Fork Salmon River. On these rivers the demand is relatively inelastic, and use would not change much with an increase in cost. This relation however, does not hold for the Stanley Basin or the St. Joe River areas, where the demand is more elastic, and use would vary considerably with a change in cost. The elasticities of demand differ for these areas largely because of accessibility and the type of outdoor recreation available. The Salmon River and Middle Fork areas are more remote, thus the activities engaged in are white-water floating or jet boating, fishing, and other more remote area activities. The parties that came to these areas were small family groups and individuals. Access to the St. Joe River and the Stanley Basin areas is much better because of highways. There is no access to the Middle Fork Salmon River and only limited access to the main Salmon River. The types of activities engaged in by recreationists on the St. Joe River and in the Stanley Basin are camping, swimming, boating and waterskiing, and backpacking into high country. These are largely family groups.

The demand in the Stanley Basin and St. Joe River areas tends to be more elastic than that for the Middle Fork and other Salmon River areas because of the nature of the recreational experiences available in these areas, the types of people who recreate in these areas, and the availability of areas relatively close by which could provide substitute types of experiences.

The Middle Fork is an "Instant Wild River", that is, a wild river created by an act of Congress (PL90-542). As such, it has received an increasing amount of publicity since 1968 when PL90-542 was enacted by Congress. Consequently many more people have been attracted to it since.

Expenditures varied from $1.90 per visitor day in the Stanley Basin for campground type recreation to $18.50 per visi-

Table 2.--*Demand Schedules for Outdoor Recreation Linear Form Equations*

Transfer cost or price	Stanley Basin	Upper Basin	Corn Creek	Lower Basin	Middle Fork	Middle Fork II	Middle Fork III	St. Joe River
	Visitor Days Consumed							
0	82.7	19.4	25.8	15.1	13.6	19.9	19.5	42.0
2	56.4	18.1	24.5	14.1	13.4	19.9	19.4	30.5
4	30.1	16.8	23.2	13.1	13.3	19.8	19.3	18.9
6	3.9	15.4	21.9	12.1	13.1	19.8	19.1	7.4
8	-22.4	14.1	20.6	11.2	12.9	19.7	19.0	-4.2
10		12.8	19.3	10.2	12.8	19.7	18.9	
12		11.4	18.0	9.2	12.6	19.6	18.8	
14		10.1	16.7	8.2	12.5	19.6	18.6	
16		8.8	15.4	7.2	12.3	19.5	18.5	
18		7.4	14.1	6.2	12.2	19.4	18.4	
20		6.1	12.8	5.2	12.0	19.4	18.2	
22		4.8	11.4	4.3	11.8	19.3	18.1	
24		3.4	10.1	3.3	11.7	19.3	18.0	
26		2.1	8.8	2.3	11.5	19.2	17.8	
28		.7	7.5	1.3	11.4	19.2	17.7	
30		-.6	6.2	.3	11.2	19.1	17.6	

tor day for floating the Middle Fork Salmon River (table 3). The consumer surplus values followed this same pattern varying from $3.05 per visitor day in the Stanley Basin to $76.88 per visitor day on the Middle Fork. The relation between expenditure and consumer surplus was quite different in each of these demand models, which indicates that they reflected area differences. The relation of expenditures to consumer surplus was greatest for the Middle Fork Salmon River (1:4.2) and least for the Corn Creek area (1:1.8). The St. Joe River ranked second to the Middle Fork (1:3.6) in the expenditure consumer surplus ratio and the others ranked as follows: Upper Basin (1:2.9), Lower Basin (1:1.6), and Stanley Basin (1:1.6).

Table 3.--*Estimated Costs and Consumer Surplus per Visitor Day*[1]

River area	Estimated visitor days per trip	Est. average expenditure	Est. average consumer surplus
	number		
Stanley Basin	12.5	$ 1.90	$ 3.05
St. Joe River 1971	27.7	2.50	9.00
Upper Basin	16.6	4.30	12.40
Corn Creek	20.4	8.40	15.55
Lower Basin	11.6	7.30	11.85
Middle Fork 1969	12.2	18.50	76.85

[1]12 hours or any part thereof.

LIKERT-TYPE SCALE ANALYSIS

A Likert-Type scale is used to study social attitudes. In such a scale, the individuals are asked to respond to each item in terms of several degrees of agreement or disagreement (Selltiz *et al.* 1961). The next step is to identify a relatively large group of items considered relevant to the subject matter being investigated, and administering these items to a group of persons familiar with this subject matter.

This was used to develop a weighted distribution of recreationists' reactions. A variety of scales were used and the basic items evaluated ranged from 9 to 22. These items were placed into four categories: (1) land-based experiences (camping, hiking, and hunting); (2) water-based experiences (fishing, swimming, boating, including jet boating and rafting, and waterskiing); (3) visual experiences (sightseeing, scenic beauty, and photography); and (4) other activities (history, archeology, and scientific interest) as shown in table 4.

The distribution of values was based on the respondents' evaluation of these experiences. Two general weighting scales were used. The first was used on the Upper

Table 4.--*Items Included in Likert-Type Scale*

Items	Stanley Basin	Upper Basin	Corn Creek	Lower Basin	Middle Fork	St. Joe River
Land Resources:						
Hunting		X	X	X	X	
Camping		X	X	X	X	
Hiking						
Horse riding	X					
Motorbike riding	X					
Backpacking	X					
Picnicking						X
Wildlife						X
Water Resources:						
Fishing	X	X	X	X	X	
Swimming	X	X	X	X	X	X
Floating	X	X	X	X	X	X
Pure water						X
Powerboats						X
Waterskiing	X					X
Visual Experiences:						
Scenic beauty		X	X	X	X	X
Photography	X	X	X	X	X	X
Sightseeing	X					X
Psychic Experiences:						
Adventure						X
Escape from society						X
Communing with nature (personal enrichment)						X
Family unity						
Isolation						
Other Experiences:						
History		X	X	X	X	X
Scientific interest						X
Other		X	X	X	X	X

ısin, Corn Creek, Lower Basin and Middle ›rk areas of the Salmon River and tribuıries. The rating scale used was: (a) ccellent, (b) important, (c) unimportant, ıd (d) no opinion. The weights attached › each of these items were: (a) excellent, ‹; (b) important, +1; (c) unimportant, -1.

The second scale was based on a relıive ranking of the importance of the ıtivities evaluated. This scale ranged rom -1, which was the least important, to , which was the most important.

The general form of the equation used › develop the weighted scores was:

$$L_W = [(2)(E) + (1)(I) + (-1)(U)]/N$$

here:

L_W=weighted score
E =number of excellent ratings
I =number of important ratings
U =number of unimportant ratings
N =the total number of observations

In other areas, the calculation was ərformed in a similar fashion although the ıting schemes were slightly different. his occurred because several types of ıting questionnaires were used. The reılts, however, were not radically affected › changing the method of rating responses.

Once the weighted values for the re›urce uses were developed, a percentage istribution for the complete recreation cperience was determined. This made it ›ssible to estimate the relative importance f each of the outdoor recreation categories. ı the first round, the definition of esıetics was limited to visual responses. ı the second round, other types of esıetic responses were considered in the ıalysis.

It is impossible to develop mutually cclusive categories. This difficulty rises because of a number of factors. For cample, there is the problem of separation. ›w does one describe an esthetic experience › that it does not impinge or overlap on ›me other part of the recreation experience? ı example is white-water floating. How are ıe visual aspects separated from the exciteənt of going over rapids? The procedure ›llowed was to assume that all these catgories were mutually exclusive.

Weighted scores (table 5) were calcuıted for each experience category and rea. These were expressed as a percentage distribution for each area. The scale appears to be sensitive to the resource base in each area, that was reflected in the ranking given each experience. There was not an "other" experience category for the Stanley Basin area because of the structure of the rating scale.

The goal of developing the percentage distributions of recreationists' responses to their wild river type of experiences was to develop an allocation scheme that would determine the distribution of the consumer surplus among the experience patterns defined by the recreationists. If it is assumed that the consumer surplus is a valid measure of the utility received by outdoor recreationists from their experiences, the distribution will indicate how they allocated this utility.

Results from the demand models were used to develop values for each experience category. This was done by using the Likert-Type scale to allocate transfer costs and consumer surplus values to the resource uses.

Table 5.--*Estimated Ratings of Recreational Experiences*

Experience categories	Observations	Total score	Weighted average	Percent
	Number			
Stanley Basin Area				
Land	629	1,168	1.86	40
Water	543	784	1.44	31
Visual	398	528	1.32	29
Total	1,570	2,480		100
Upper Basin				
Land	205	298	1.45	26
Water	236	233	0.98	18
Visual	303	558	1.84	34
Other	94	110	1.17	22
Total	838	1,199		100
Corn Creek				
Land	275	443	1.61	27
Water	396	550	1.39	23
Visual	348	683	1.96	31
Other	138	155	1.12	19
Total	1,157	1,801		100
Lower Basin				
Land	444	507	1.14	24
Water	613	597	0.97	21
Visual	606	1,035	1.71	37
Other	225	188	0.84	18
Total	1,888	2,327		100
Middle Fork River				
Land	785	640	0.82	16
Water	1,304	1,734	1.33	26
Visual	922	1,594	1.73	35
Other	450	509	1.13	23
Total	3,461	4,477		100
St. Joe River				
Land	1,040	1,470	1.41	24
Water	955	1,188	1.24	22
Visual	740	1,295	1.75	30
Other	930	1,268	1.36	24
Total	3,665	5,221		100

The estimates shown in table 6 are based on a 1969 to 1971 data base for both the estimated expenditures and the consumer surplus values derived from the demand equations. The average expenditures and consumer surplus estimates were distributed using the percent distribution shown in table 5. The values shown in table 6 can be interpreted as the values related to each experience category based on either expenditures or consumer surplus values per visitor day.

Table 6.--*Estimated Average Values per Visitor Day by Outdoor Recreation Experience Categories*

Area		Land	Water	Visual	Other	Total
EXPENDITURES						
Stanley Basin	(1971)	$ 0.76	$ 0.59	$ 0.55	$ --	$ 1.90
St. Joe River	(1971)	0.62	0.58	0.70	0.60	2.50
Upper Basin	(1969)	1.12	0.77	1.46	0.95	4.30
Corn Creek	(1969)	2.27	1.93	2.60	1.60	8.40
Lower Basin	(1969)	1.75	1.53	2.71	1.31	7.30
Middle Fork	(1969)	2.96	4.81	6.48	4.25	18.50
CONSUMER SURPLUS						
Stanley Basin		$ 1.22	$ 0.95	$ 0.88	$ --	$ 3.05
St. Joe River		2.25	2.07	2.52	2.16	9.00
Upper Basin		3.22	2.23	4.22	2.73	12.40
Corn Creek		4.20	3.58	4.82	2.95	15.55
Lower Basin		2.84	2.49	4.39	2.13	11.85
Middle Fork		12.30	19.98	26.90	17.67	76.85

These data were extrapolated from the visitor day basis to the resource values by multiplying the average per-visitor-day values by the estimated number of visitor days of use in the area (table 7). The expenditure and consumer surplus values all reflect the distribution of the experience categories as defined using the Likert-Type scale analysis. As a result the values for the experience categories also reflect their use levels. It is assumed that the level of use in an area reflects the resources of the area and the quality of the experience available in the areas.

The concept of consumer surplus is valid because it is used in determining the net benefits of water resources projects (Water Resources Council, *et al.* 1973). In the case presented here, the totals in table 6 are the total expenditures and consumer surplus values for outdoor recreation in each area. The consumer surplus values can be used as a net economic benefit and compared with the net economic benefits estimated for water resources development projects on a one-to-one basis. Table 7 also provides additional information on how the recreationists ranked their experiences in terms of the value each category received.

The recreationists ranked some experience categories as more important than others. What is interesting is that those categories (visual and other) that can be identified as esthetic tend to rank quite high. Visual included the recreationists' reaction to scenic beauty and opportunities to sightsee and practice photography. The other category included such items as the history and archeology of the area and scientific interest. In the case of St. Joe River, Upper Basin, Corn Creek, Lower Basin, and Middle Fork Salmon River, the visual category ranked higher than all the other experience categories. Only in the Stanley Basin was the visual resource lower than the other categories evaluated. The reason for this was related to the way the

Table 7.--*Estimated Aggregate Values for Recreation Areas by Experience Categories, 1970*

(In thousands of dollars)

Recreation area's estimated visitor days (thousands)		Land	Water	Visual	Other	Total
EXPENDITURES						
Stanley Basin	(703.1)	$ 534.4	$ 414.8	$ 386.7	$ --	$ 1,335.9
St. Joe River	(295.0)	182.9	171.1	206.5	177.0	737.5
Upper Basin	(316.0)	353.9	243.3	461.4	300.2	1,358.8
Corn Creek	(606.8)	1,377.4	1,171.1	1,577.7	970.9	5,097.1
Lower Basin	(539.5)	944.1	825.5	1,462.1	706.7	3,938.4
Middle Fork	(20.4)	60.4	98.1	132.2	86.7	377.4
Total	(2,480.8)	$3,453.1	$2,923.9	$4,226.6	$2,241.5	$12,845.1
CONSUMER SURPLUS						
Stanley Basin	(703.1)	$ 857.9	$ 667.9	$ 618.7	$ --	$ 2,144.5
St. Joe River	(295.0)	663.8	610.7	743.3	637.2	2,655.0
Upper Basin	(316.0)	1,017.5	704.7	1,333.5	862.7	3,918.4
Corn Creek	(606.8)	2,548.6	2,172.3	2,924.7	1,790.1	9,435.7
Lower Basin	(539.5)	1,532.2	1,343.4	2,368.4	1,149.1	6,393.1
Middle Fork	(20.4)	250.9	407.6	548.7	360.5	1,567.7
Total	(2,480.8)	$6,870.9	$5,906.6	$8,537.3	$4,799.6	$26,114.4

Likert-Type scale was developed for the Stanley Basin.

The land and water categories were assumed to reflect recreationists' perception and evaluation of their outdoor recreation activities, such as fishing, swimming, hunting, camping, and other activities. The visual and other categories tend to reflect more the psychic aspects of outdoor recreation experiences.

The procedure is quite flexible. The key to the analysis is in the Likert-Type scale. The type of scale developed can influence the nature of the model used to estimate the values in the experience categories. At the present level, the categories were defined in terms of users' direct responses. The use of indirect responses would most likely improve the sensitivity of the measurement of esthetic parameters, particularly those related to valuing esthetics.

The relation between the experience categories may be evaluated in alternative ways when one considers esthetics. It would be quite easy to combine the visual and other categories under the esthetics heading. These items were history, scientific interest, and archeology, which tend to increase one's appreciation of an area. If this approach were to be used, the impact on the estimated value would be great. The "other" category accounted for a range of from 18 to 24 percent of the distribution of values.

An example of the increases in esthetic value would vary from none for the Stanley Basin, which had no other category due to the design of the questionnaire used to develop the Likert-Type scale, to 58 percent of the total value on the Middle Fork. At the margin, the St. Joe River would gain the most (24 percent increase); the Lower Basin area the lowest (18 percent increase).

The range of esthetic values involved would vary greatly. The consumer surplus value related to esthetic appreciation would increase from $548,700 to $909,200 on the Middle Fork, where the percentage increase was the greatest. In the Lower Basin area, the consumer surplus for esthetic value would increase from $2,368,400 to $3,517,500. The magnitudes reflect the quantity of use each area receives.

Obviously the magnitude of esthetic values measured can be manipulated to achieve the type of result desired using the consumer surplus technique. Goals must be carefully defined in this kind of research.

CONCLUSIONS

The quantifying of esthetic values is yet an imperfect art. The procedures we developed must be looked upon with skepticism because of the limiting assumptions made. These assumptions were necessary in order to make any progress at all toward the goal of quantifying esthetics in any realistic way.

However, if water resource planners and researchers are willing to accept these assumptions and the overall approach, it would be possible to include the direct consideration of esthetic values quantified in the manner done in this report as a part of the process of evaluating wild and scenic rivers. This should be done with the full knowledge and understanding of the limitations of the method. If done in this fashion, it would permit planners to directly indicate the value recreational users put on the experiences they have with the water resources being evaluated.

This technique needs more study and research to determine its consistency, and the stability of the distributions that have been developed. Will they change as the cost of recreation increases? Economic theory would lead one to believe so, just as the quantity of recreation consumed would tend to vary with the cost of the recreation trip.

Although esthetics ranked high, based on the visual experience category, it should not be assumed that people would be willing to pay high prices to enjoy them. Esthetics are only a part of the overall recreation experience; therefore, the lack of a direct pricing mechanism may be the reason it had such a high value. If fees were imposed on recreation based on the results of the demand analysis, recreationists' responses to increasing cost levels for outdoor recreation would likely be reflected in less use. The elasticity of demand would be an important factor in accounting for the value of all the experience categories.

The Likert-Type scale indicates the way recreationists would distribute the value of their experiences among the several categories. The option value is defined as the value existing for a good or service that should be added to consumer surplus when there is uncertainty in demand. This is not included, therefore, the Likert-Type scale analysis most like underestimates the value of esthetics (Cicchetti and Freeman 1971). However because no other approximations of esthe value have any emperical basis, this Likert-Type consumer surplus approach is a useful approximation to the quantifica of esthetic value.

VARIATION AND RECREATION QUALITY IN RIVER MANAGEMENT

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ABSTRACT.--Variation in the river environment is a major determinant of the quality of river recreation experiences. In river canoeing, there are four main sources of variation: psycho-social variation, landscape variation, river variation, and variation inherent in the activity itself. By considering how these sources of variation interact, it should be possible to affect the quality of the recreation experience and accomplish other management objectives as well.

Imagine three families on canoeing vacations. For the first family, everything is perfect. The days are sunny and warm, the evenings just cool enough, and a gentle breeze carries the sweet smell of the forest. The river is just difficult enough to provide some excitement without undue risk.

Members of the second family are experienced white water canoeists. But they find that the stream recommended by a friend meanders lazily through pine plantations and offers little challenge. Furthermore, there is little wildlife or change of scenery to break the monotony. Feeling rather cheated, these people are not enjoying themselves and are anxious to get the trip over with so they can do something else.

People in the third family have bitten off more than they can chew. They have chosen a stream with rapids beyond their ability and would gladly quit. However, it is impossible to paddle upstream to their starting point, and they have no options for getting out until reaching their destination. They have already tipped over twice, have lost some of their equipment, and have badly dented their aluminum canoe. They are nearly terrified, and their trip has become an ordeal to be survived rather than a pleasure.

These three examples represent variations in recreation quality, and most of us can readily recall similar variations. Providing quality recreation experiences should concern all land managers who administer rivers used for recreation. After all, providing people with benefits is the real reason resource managers are in business. Yet, what is quality? Too often we are ready to prescribe what we like best as the formula to be applied across the board. The trick, however, is to find a logically consistent framework that will help us understand recreation quality for other people, not just ourselves (Wagar 1966).

In this paper, we will examine the importance of variation in providing quality recreation on rivers. After a short look at basic relations, we illustrate their application to one type of river recreation--canoeing. While the relations we suggest stem from basic psychological theory rather than empirical testing, we do feel that they offer the river recreation manager some insights into concrete management problems.

THE NEED FOR VARIATION

As biological and social creatures, people have a number of different needs: hunger, thirst, cravings for affection, physical activity, etc. All play an important role in motivating human behavior. One of the least obvious, but most important of these needs is the need for variation in environmental stimulation. Work on this need began when it was discovered that prolonged exposure to monotonous environments could have pathological effects on people (Herron 1957). Imagine participating in a sensory deprivation where all stimulation is blocked out. In such settings, people experience intellectual disruption, severe emotional disturbance, and even hallucinations (Dember 1960). While this is, of course, extreme, the implications are quite clear--people dislike simple, monotonous, unchanging environments.

On the other hand, some environments may offer excessive amounts of variation or stimulation. Remember the first time you drove in some large and unfamiliar city? While everything was still new, you probably were acutely aware of the enormously varied stimuli with which you were bombarded. Cities are normally places of high stimulation because of traffic, noise, bright lights, and the virtually endless variety of people, places, and objects, and this in itself may have pathological consequences (Milgram 1970). Excessive variation in a chaotic environment quickly overloads people and creates feelings of stress.

Fortunately, we can usually adapt to levels of variation and stimulation that may at first seem overwhelming. The routine subway ride, during which a New Yorker dozes or reads his paper, would at first probably terrify the Australian Bushman as it rushed him noisily through darkness with unexplained noises, flickering of lights, smells, and lurching changes in direction. More technically, repeated exposure to the same types of stimuli tends to reduce the impact that those stimuli have on a person (Walker 1972). Therefore, we expect that the expert canoeist and the novice might have very different emotional reactions to the same stretch of river.

Thus, there is a relation between the amount of variation in an environment, and people's preferences for that environment. Environments that are too simple and unchanging are disliked, as are environments that are excessively complex or chaotic. In between, there is a mid-range of variation that people prefer, and at some point there is an optimal level of stimulation. This would be the point of greatest preference (fig. 1). The three families mentioned above can be located on this preference curve, and by thinking in these terms, we can begin to understand why they reacted as they did.

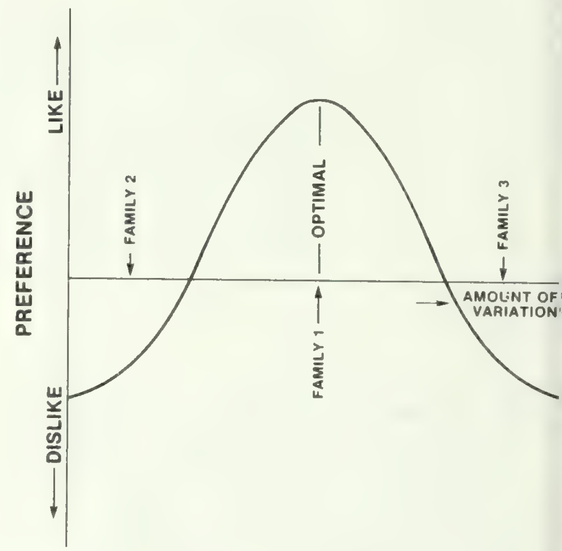

Figure 1.--*Relation between preference and amount of variation (adapted from Walker 1972).*

In this way, management has an opportunity to affect the quality of the recreation experiences a particular river provides by regulating variation. This is a general principle that holds true for different types of rivers and different forms of river recreation activities. What follows is an attempt to show how this might be applied to one type of recreational activity: canoeing in a natural environment.

THE CANOEING ENVIRONMENT: SOURCES OF VARIATION

There are four main sources of variation in river canoeing: psycho-social variation, landscape variation, river variation, and variation inherent in the activity itself. Each of these contributes to the quality of the recreation experience.

Psycho-Social Variation

Psycho-social variation encompasses differences both within and between individuals. Important sources of individual variation include variation in abilities, physical condition, and experience levels as well as individual differences in expectations, satisfactions, perceptions, and motives (Knopf *et al.* 1973). Sources of social variation include other river users (canoeists, fishermen, riparian property owners, etc.) and management personnel (rangers, outfitters). Relations between canoeists and other river users may range from coexistence to conflict (Knopf *et al.* 1973, Peterson 1974, Lime 1975b), although the relations between canoeists and management personnel appear cordial (Peterson 1974).

Over some of these sources of variation, the manager has little or no control; an argument between friends can ruin an experience. On the other hand, many of the management techniques developed in wilderness areas may be applicable to river management. For example, in canoeing the group may become the basic unit of social interaction--the presence of other groups is resented much more than the numerous numbers of one's own group. Control of numbers, use periods, and itineraries can be used to reduce contacts between groups. When possible, careful control of concessions and land uses should be exercised. Zoning and land acquisition can reduce the impact of competing uses by separating them, either in space or in time. For example, water skiing is sometimes restricted to certain hours, and horsepower limits and paddleboat regulations can help to keep different kinds of boaters separate. Most of these techniques are familiar to resource managers.

Landscape Variation

Much of the variation in canoeing comes from the landscape around the river. To illustrate how trees can be managed to create a more stimulating visual environment for canoeists, let's consider an example of a monotonous reach--one that is usually dull and uninteresting. Imagine a sluggish, nearly straight stream, about 80 feet wide with trees and vines forming a wall of vegetation right at the water's edge. This corridor-like reach of stream could be made more interesting merely by altering the forest vegetation to create different visual effects.

Along the river banks, vegetation is often dense and luxuriant due to the large amounts of available moisture and sunlight. This vegetation frequently creates a visually impenetrable wall. There are a number of different ways that this wall can be modified to create variation. First, the distance between the forest edge and river bank can be varied. Trees can be harvested to create meadows or clearings at intervals. The size of the opening and the setback of the far edge can be varied from one setback to the next. Thinning and pruning out branches, vines, and understory vegetation is another way of breaking up the wall of vegetation. Once the initial edge is opened, stocking levels can be varied in the stand beyond to permit more or less visual penetration.

Controlling the sequence of stands is also important in producing high quality experiences. Long stretches through any particular type will produce boredom and monotony no matter how interesting that type seemed at first. Type changes from old to young conifers, to meadow, to hardwoods, to shrubs, etc., will keep the amount of landscape variation fairly high, thus maintaining visual interest. Hopefully, such manipulations could be coordinated with other forest management activities, in order to reduce the cost of applying them.

River Variation

The river itself is a major source of variation. Its width, depth, distance to the next bend, the height and slope of the banks, water color and purity, and the content (animal, vegetable, or mineral) are all variable. Islands, too, add variety and stimulate user curiosity. But, for canoeing, perhaps the most important sources of variation are the speed of the water and the extent and difficulty of rapids, if any. In some cases, where there is an excessively long stretch of calm, slow water, it may be possible to narrow the channel and add rocks or boulders to break up the monotony. Or, if rough water predominates, it might be slowed in some places by creating pools.

Change between river conditions is essential for quality recreation experi-

ences. Too many stretches of rapids may contain too much information and require the canoeists to be ever alert, reducing the quality of the experience. On the other hand, a long, straight, calm stretch of river can become rather like driving through the midwest in the middle of the night. Balance is required.

Variation in the Activity

Canoeing is, in essence, a journey through both time and space. As such, some variability is inherent in the activity itself. Over time, the canoeists themselves may change--blisters develop, muscles begin to ache, backs get sunburned, people become more relaxed, etc. In fact, we may be dealing with very different sets of people on the fourth day of a trip than we were on the first.

From a spatial standpoint, virtually every stroke of the paddle changes the canoe's position. Since most canoeists have limited time, they will probably have goals in mind--that is, specific physical points that they will strive to reach by a certain time. A goal might be a campsite, a point of scenic interest, a portage, or the end point of the trip. Managers can create or remove goals, and also provide landmark stimuli that show canoeists how far they have to go to reach the next goal. Adding landmarks or attractions can increase the quality of the experience.[1]

INTERACTION BETWEEN SOURCES OF VARIATION

When we speak of recreation, we usually mean a total experience. Each source of variation contributes to this total. While it may suit our purposes to break them down into convenient subgroups, in fact they act jointly to produce a total canoeing experience. Therefore, we need to consider how they fit together from both a management and a recreationist point of view.

First, canoeists see the landscape from a specific vantage point. Their range of vision will be limited primarily to a 18 range centered straight downstream. Thu the view upstream should probably concern us less than the view downstream.

Another limiting factor can be the height and slope of the banks. High, st banks may create a short viewing distanc limiting the need to deal with any but streambank vegetation. Other vegetation may be more important where banks are lo and the line of sight is nearly horizont

In some instances, the sources of va iation can themselves be limiting. In lo calm reaches of rivers (i.e., when river variation is low), providing variation i the landscape may be especially importan In areas of moderate white water, howeve there may be less need to manage the lan scape. In fact, a competing land use ma be less noticeable here than elsewhere be cause people's attention will be focused the river. In areas of extreme hazard (stretches of river with dangerous white water or "sweepers"), it may actually be desirable to promote monotonous landscape in order to focus people's attention on t river. Thus, by manipulating these sourc of variation relative to one another, it should be possible both to affect the qua ty of the experience and accomplish other ma agement objectives as well.

CONCLUSION

In this paper, we have tried to exam e the relation between variation and recreation quality, and to illustrate how th might be applied to river management for canoeing. There are probably other sourc of variation, but the same basic relation should apply, both for canoeing and for other kinds of river recreation as well. Indeed, many of the applications to other activities may be similar to those descri here. However, variation is only one det minant of recreation quality. In some cases, stimuli that could provide variati might conflict with other motivations of users, thereby reducing the quality of th experience. For example, a simple way to provide variation along a scenic river would be to put up billboards of differen sizes, shapes, and colors. Obviously, ho ever, this would conflict with some of th other important motivations of canoeists like the desire to experience an unchange

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[1] *More, T., and G. Buhyoff. On-site behavior in forest recreation areas: a theory of recreation quality. Unpubl. manuscript on file at Northeast. For. Exp. Stn., Amherst, Massachusetts.*

atural environment. Careful thought is ecessary.

Yet, the creative manager can still do uch to influence recreation quality by con- idering the role of variation. In most ases, we should strive to heighten the uality by providing variation. However, n a few cases it may be desirable to man- ge for reduced quality by promoting monotony. Managing for variation can be a useful tool for accomplishing management objectives.

ACKNOWLEDGMENT

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EFFECTS OF NATIONAL PARK SERVICE AND FOREST SERVICE REGULATIONS ON CONCESSION OPERATIONS

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ABSTRACT.--Examines the impact of USDA Forest Service and National Park Service regulations on elements of market structure and conduct for commercial float trip companies under their respective jurisdictions. Discusses price and quantity aspects of demand and differences in regulations.

The underpinning of our social and economic system is the allocation of scarce resources through the free market process. Basically, in most industrial settings we assume that resources will be allocated to uses where they will fare best. This means that the price system will value resources consistent with demand and that production, land, labor, and capitol will be channeled into productive uses to provide needed services and products. The concept of demand therefore, has two dimensions: how much is sought and at what price. If the supply of a particular product falls short of the amount desired by consumers, prices will increase. This provides a signal to industry to transfer resources to that pursuit which will best meet consumer expectations.

Unfortunately, workably competitive markets (an assumption of the free market process) are not found in all industries. Even if they were, there are still externalities and imperfections in the market process that tend to justify the existence of independent regulatory agencies to regulate monopolies or near monopolies that are likely to develop under such imperfect conditions.

The classic example of a highly concentrated industry under the regulatory oversight of an independent commission is the public utility industry. In this industry, the fixed costs incurred by a fi are of such magnitude that the long-run average total cost for a firm declines. Therefore, as the price charged must cov average cost, the consumer is offered lo prices by a regulated monopoly than woul be available from multiple producers in free market setting. There are other su imperfections as a limited physical spectrum (the broadcasting industry), very scarce resources (extractive industries) and at least theoretically, chronic exce capacity (found in overly mature or exploited markets).

Externalities also are not consider adequately by the market process. For example, the costs of pollution or of social benefits, such as education, may no be properly considered by industry or co sumers because the private returns are n sufficient to cause appropriate investme in them.

There are conditions rapidly develo ing in markets that rely upon public lan and water resources administered by gove mental agencies. One is the commercial of scenic and white water rivers on publ lands. These rivers are a very scarce re source. The utility derived by consumer (float trip passengers) can be substanti ly diminished by overuse of the resource.

There are numerous analogies that can be drawn between the traditional, regulated industries, and the river running industry. For example, the Civil Aeronautics Board (CAB) allocates routes to various airlines ...the National Park Service (NPS) allocates sections of rivers to various concessions. The CAB regulates the number of flights and origin and destination of these flights...the NPS regulates the number of floats and points of embarkation and debarkation. The Interstate Commerce Commission (ICC) establishes load limits for common carriers...the USDA Forest Service (USFS) establishes carrying capacities for rafts. The Federal Communications Commission (FCC) regulates entry into the broadcasting industry through licenses...the USFS regulates entry by issueing limited special use permits. Thus, resource management agencies have been placed in the position of the traditional regulatory agencies. The rapid escalation in use of the scarce resources they administer will force these agencies to examine first, the ecological consequences; and finally, the economic consequences of regulations and resource use much in the same way the traditional regulatory agencies have had to address such issues.

An example can be isolated in the USFS regulation of ski areas. Initially, special use permits were routinely granted; then safety and environmental considerations became more important; concern for a quality experience followed; now lift ticket pricing, design specifications, and restricted entry are serious problems. Recreational use provided by commercial outfitters on rivers is now probably well into the second level of evaluation by most resource management agencies.

THE PROBLEM

Increasingly, various regulations are being added to the existing list with little understanding of their effect upon the economic characteristics of commercial outfitters or float trip users. Most policies and regulations are intended to enhance and protect the environment and scenic quality of wild and near wild rivers. However, the results may be counter productive or at least diminished from what was intended as a consequence of unanticipated economic impacts. For example, user limits placed on certain river systems (an economic production quota) has resulted in a black market for river trips that is contributing to political tension and an overall reduction in the quality of the river experience. Price ceilings (price control) result in a production, cost-cutting orientation by commercial outfitters that tends to reduce the quality of the float trip experience and contributes to crowding. While the intent was to provide a bargain for the float trip customer, the net effect is the opposite. Seemingly innocuous regulations, e.g. life vests, have economic overtones that may adversely affect the overall safety of a float trip operation. The added increment of safety as a consequence of the better and more expensive life vests that might be required may reduce needed expenditures for maintenance on floating or land/air transportation equipment and/or boat operator training. This could result in a lower overall safety factor. One can't place limits on use, ceilings on price, requirements on certain types of investment, and restrictions on certain activities and expect that *all* the results will be those that were intended and directly related to the specific regulations. In fact, this is precisely the reason economic impacts of particular "environmental" decisions should be studied and are specifically required by the Environmental Impact Statement (EIS) process.

The need for an understanding of the economic consequences of regulations and administrative action is even more critical where agencies exercise specific control over the business practices of a firm. Frequently, the result of a particular regulation or administrative decision by regulatory agencies may be witnessed outside the geographic limits of their regulatory authority. The effect in a ski area may be economical, social and/or environmental. When ski area is built in a canyon, it may affect water quality for a town below, cause a change in the social structure of the community, and require increases in the bonded indebtedness and taxes to provide the necessary services--water, waste removal, protection, health, school, etc. Or, a user limit might reduce the tax base, cause unemployment, and allow the appearance of the community to deteriorate. Of more immediate concern perhaps is where two resource management agencies are in close proximity and decisions in one, the NPS for example, may have an immediate effect upon the other, the USFS, for example.

THE SNAKE RIVER CASE

The Snake River in northwestern Wyoming offers an excellent opportunity to examine the close relation between two resources regulating agencies, the USFS and NPS. The Snake River originates in the Teton Wilderness area and gains substancial size as it flows through Yellowstone National Park. As the river exits Yellowstone, its size and access affords the first opportunity to float the river commercially or privately. There is a short section (3 miles) of white water, a four to six rating depending on water and weather conditions, then a high quality scenic section that flows through the Rockefeller Parkway into Jackson Lake and Grand Teton National Park. This section of river, however, provides only a very small portion of the user days on the river. The water flow is dependent upon snow melt; hence, it only provides spring and early summer floating.

The Snake River below Jackson Lake Dam is subject to fluctuation between early summer and fall; however, the impoundment behind Jackson Lake Dam provides some stability (an average flow between 3,000 and 4,000 ft^3/s during the summer with a floatable range between 400 ft^3/s and 15,000 ft^3/s). The section between the entry of Pacific Creek (4 miles downstream of the dam) and Moose provides a 25-mile scenic river within Grand Teton National Park. There are intermediate entry and exit points and 80 to 90 percent of the commercial floaters are on the section between Pacific Creek and Deadman's Bar or Deadman's Bar and Moose. The commercial outfitters operate under concession permits issued by the NPS.

Farther to the south, the Snake River flows through the Snake River Canyon, which is under the jurisdiction of the USFS. In the past, administration of the Snake River Canyon was under the Targhee National Forest. Since October 1976 however, it has been administered by the Bridger-Teton National Forest. During 1976-77, the Bridger-Teton will make a study to determine the extent to which the Snake River Canyon will qualify for designation under the Wild and Scenic Rivers Act. The commercially-run section of river is approximately 8 miles long with short rapid stretches rated up to a 7 or 8.

Commercial float trip operations began in the late 1950's on the section of river in Grand Teton National Park. Lit regulation was in evidence and float tri did not have a commercial character. St were frequently made to view animals and investigate bald eagle, red tail hawk, o prey, and great blue heron nesting areas This practice was discontinued voluntari between 1966 and 1968, and, subsequently by NPS mandates when use levels became t great and scheduling became a problem. motors are allowed on the Snake River wi in the Park. Similar growth patterns occurred more recently in the Snake River Canyon, but motors were not excluded. H ever, under recently-issued use permits, motors are not generally permissible exc on rescue craft and to tow boats through the backed up waters of Palisades Reservoir.

A Categorization of Ecenomic Regulations

Economic regulations governing comme cial use of rivers are applied at two lev els. These regulations by the USFS and N affect the market "structure" and "conduc of the industry.

The terms "structure" and "conduct a familar to most economists as two of the principle components of the Industrial Or ganization (IO) model. In this case, how ever, the constraints on structure and co duct are a consequence of USFS and NPS re ulations and management policy rather tha the unregulated workings of the market place. Structure refers to the character istics of a particular industry rather th that industry's activity. Elements of structure include concentration, which re fers to the number of firms and their respective market shares; entry barriers, which refers to the type and size of econ mic limitations facing firms attempting t enter the industry; and, to the extent to which the industry is integrated, which refers principally to a relation in successive functions dependent upon one another in the delivery of the product to the consumer. These areas are of princip concern to the resource management specia ists of the USFS and NPS as is evidenced existing regulations. Some economics may isolate other elements of market structur there certainly are other supply and dema constraints that are characteristically associated with structure.

Structure refers to the characteri-

tics of an industry, conduct refers to the activities or behavior of firms in that industry. Traditional economic theory examines conduct options (1) decisions regarding price and (2) decisions regarding output. However, conduct can be expanded to include those activities of the firm related to the marketing of its products or services: pricing, product differentiation decisions, personnel decisions, transportation, advertising, and generally any other aspect of the business associated with providing a float trip experience for river users.

The USFS uses special-use permits to commercial float trips on the canyon section of the Snake River. In their applications for such permits , commercial outfitters request boat launching and exit sites, stops in route, and describe the type of floating craft to be used. The applicant also forecasts the potential number of individuals who will be floated during the season. A permit is then issued that typically includes the following items: (1) use sites on national forest lands (2) restrictions concerning the use sites if any (3) lunch stops and camp sites (4) types of boats authorized (5) number of boats permitted at one time (6) boat names (7) the period of use (8) the initial authorized use as an estimate of the number of people to be served and (9) the fee, calculated at 25¢ per person (minimum fee of $25) to be paid based upon the estimate of the initial use. There are 32 other general provisions that clerify and expand the basic special-use permit.

Most of the USFS regulations affect the conduct of float trip companies rather than the structure of the industry. The more important regulations affecting structure and conduct are as follows. The number of permits to float the river have been fixed by the Forest Service on the basis of those issued in 1973 and 1974. Hence, entry into the float trip industry may only be allowed should an existing firm choose to exit the industry. Even then, however, a new firm may not enter the market if any existing firm chooses to purchase the allotment of the firm which is leaving. Recently, the USFS has allowed existing float-trip companies to buy the allotment of firms leaving the industry. This one single regulation of structure affects the concentration of the industry, entry barriers, the level of industry product differentiation, and integration within the industry. As a consequence of this constraint, the USFS has become the surrogate for competition and is forced into a position of regulating specific aspects of conduct.

The most important of the regulations of conduct concerns the number of boats a permittee is allowed to have on the river at one time. The number is based on the average number of boats floated by the permittee in the 1973-74 base years. In addition, 25¢ per person fee is charged each of the outfitters. Hence, if a particular outfitter floats 10,000 persons, their fee payable is $2,500. Each permittee is required to maintain insurance at minimum levels of $10,000 for property damage and $25,000 for singles case, and $25,000 for multiple case personal liability. Coast Guard-approved life vests must be provided for each passenger including the boatman. However, their regulation does not require that the vest be worn by the passengers. The USFS encourages the vests to be worn because they notify insurance carriers if they notice that passengers are consistantly not wearing the life vests. All of the above regulations of conduct affect the price and output decisions of the various firms.

There are two other notable regulations affecting conduct that probably do not have an impact on price or output for the various firms. (1) A trip ticket must be filled out for each passenger in triplicate; the first page is deposited at the launch site, the second at the exit site, and the third retained by the permittee. The tickets are used to calculate the final franchise fee. (2) The USFS also requires that all advertising be truthful and stipulate the specific National Forest lands within which the permittee is operating; however, it does not require approval in advance for advertising.

The NPS offers many similar regulations but includes a few additional regulations. Generally NPS regulations are more pervasive than USFS regulations.

NPS limits the number of concessions to those that were in existence in 1972. Three-year contracts are issued except for three concessions whose right to operate on the river is included as part of their overall concession permit to provide food

and lodging facilities among other types of tourist related activities. The NPS also has a mandate under public law that the concession contracts cannot be transferred or assigned. In fact, Public Law 89-249, The Concessions Policy Act, specifically forbids chattel value to accrue to the concession contract. This of course poses an interesting dilemma for the National Park Service because this makes permits extremely valuable. Several concessionaires who have ceased to operate on the river, however, have not been able to sell or transfer their permits because the NPS will not reallocate the user days. Recently, one concession permit was transferred to an existing concessionaire by the NPS. The transfer basically means that the concessionaire is allowed to launch an additional number of trips per day. As the concession permit was reissued by the NPS and not sold by the former concessionaire it is unlikely that any value did accrue to the former concessionaire unless there was a private transaction between the recipient of the new allocation of the user days and the former concessionaire.

NPS regulations like USFS regulations limit the normal competitive aspect of a market place as a consequence of entry, exit, and trade among the member firms of the industry. The effect is to develop very high artificial entry barriers and, consequently, a concentrated market.

The NPS has two additional regulations that affect elements of market structure. The types of boats used must conform to general NPS standards. While not of major significance, this regulation does have some impact on the amount of product differentiation and the general investment decisions for the industry. The NPS also restricts concessionaires to launch sites. This constraint actually produces a spatial duopoly, of sorts, because certain sections of the river become allocated specific concessionaires.

Although there are differences between the USFS and the NPS approaches to regulating the commercial users of the Snake River, these differences as measured by the structural impacts are not too significant. This is not because the regulations are trivial. The limiting of commercial permits to those in prior existence, does have a major affect on the industry. Even the Civil Aeronautics Board (CAB) does not exercise such absolute control. The CAB commissioners recognize the positive aspects occasional entry, exit, and transfer of routes. One difference is the source of the authority for each. The USFS regulations have a more informal land manageme policy background than do the NPS regulations. The USFS regulations are basical supported by a general mandate to manage public lands under their jurisdiction. NPS situation, however, has a specific c gressional mandate in the form of the Co cessions Policy Act.

The specific control of conduct by t two agencies has some notable difference In contrast to the USFS policy of limiti the number of boats at one time and limit ing certain permittees to specific launch ing times, the NPS simply states that the total number of trips taken during any on day is limited by a formula based upon pr or use in a base year. Thus, in the one NPS concessionaire can have 20 trips on t river at one time. However, under normal operating conditions, trips are usually dispersed throughout the daylight hours. At the more popular launch times and approximately 2 hours after launch at the more popular landing times, crowding on t river and in particular crowding around e try and exit points can be a serious problem; more so under the NPS jurisdiction than under USFS jurisdiction.

The NPS has a franchise fee system based upon a graduated scale calculated a a percentage of gross income. The fee schedule is as follows: first $40,000 of revenue, 1/2 of 1 percent; from $40,000 t $100,000, 1 percent of total revenue; and over $100,000, 1 1/2 percent of total rev nue. Certain operating expenses may be d ducted from gross income prior to calculating the franchise fee. Hence, assumin 10,000 persons were floated by a particul commercial trip, the NPS fee would be approximately $600 while the USFS fee would be $2,500. It may seem that the concessionaire under the NPS jurisdiction has t advantage of a better fee system; however 10,000 passengers translates into total revenue of $100,000 under the NPS jurisdiction and 10,000 passengers translates $150,000 under the USFS jurisdiction. On an equilivalent total revenue basis, the NPS commercial outfitter pays slightly le rent for his use of the asset. However, their fees cannot be considered a financi burden for the rent of a protected market position insulated from outside competition.

Other regulations governing conduct nder the NPS system are more specific than hose of the USFS. For example, advertising must receive prior approval; the NPS pproves all prices; full accounting statements must be submitted annually; a 10-trip raining period is imposed on all new boatmen; first-aid training for boatmen is mandatory; the concessionaire must carry insurance but, the levels are not specified; life vests must be carried; and there is an upper limit on the number of boats which may be launched in any one day. Generally, if the NPS so chooses, they exert regulatory authority over conduct than does the USFS.

Supply-Demand Relations

One could correctly conclude that the two most important effects the regulating agency has on the float trip industry are limits on supply (structure) and the regulation of price (conduct). Figure 1 outlines the potential problems associated with limits on supply and price. Notice that the supply of passenger days could increase as price increases up to the level of output (passenger days) Q_2 where output is constrainted. Suppose the demand for float trips is given by the demand curve, D_1D_1. The equilibrium price is P_1 and the equilibrium output is Q_1. If the demand curve should shift to D_2D_2, price would increase to P_2 and the quantity of output to Q_2. Now, if demand shifts even further to D_3D_3, the equilibrium price increases to P_3 but output remains at Q_2 because of the constraint on output. Thus, with the current regulations on supply, price would increase in order to clear the market place and the quantity of output would *not* change. If prices are not permitted to increase to P_3 but remains at P_2, demand will exist for Q_3 passenger days. If such excess demand is allowed to persist, some other means of rationing must be employed, i.e., first come first served, attractive

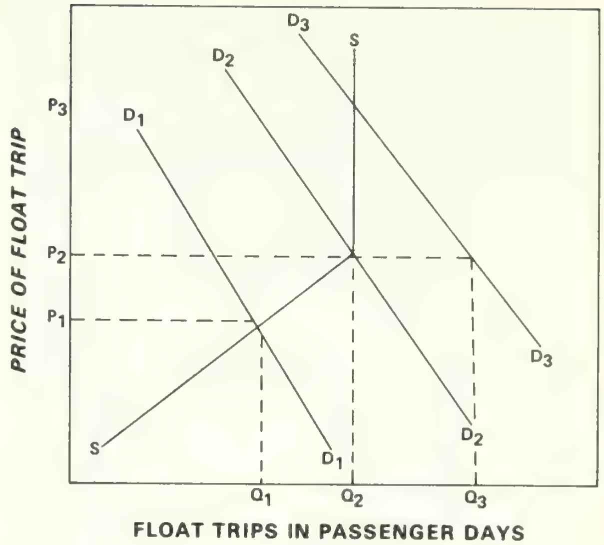

Figure 1.--*Impact of supply constraint on prices and output of float trips.*

blondes only, age, etc. The issue then becomes whether or not the new rationing process is as equitable, effective, or efficient as the price system.

Comparing the supply-demand schedule in figure 1 with the Snake River experience under NPS jurisdiction shows how price has influenced the total number of commercial floaters. Table 1 presents float trip use data on the section of river under NPS jurisdiction. The annual rate of growth is 0.25 percent. And, the number of commercial floaters has remained constant. However, from 1973 through 1976, the average price of a float trip rose from \$7 to \$9.50. This is an average annual increase of 10.72 percent. It is obvious that demand has increased by some measure. Or, as expressed in figure 1, demand has shifted from D_2D_2 to D_3D_3. The fact that requests for float trip price increases were approved by the NPS probably explains why the NPS did not have to provide some rationing scheme to river use or do battle

Table 1.--*Number of floaters on the Snake River in Grand Teton National Park, 1973-1976*[1]

Year	Commercial trips	Commercial customers	Private floaters	Total use	Commercial	Private
	- - - - - - - - -	*Number* - - - - - - -			- - *Percent* - -	
1973	6441	67,500	6,500	74,000	91	9
1974	5688	59,500	7,000	66,500	89	11
1975	6515	68,277	4,250	72,527	94	6
1976	6382	68,002	3,800	71,802	95	5

[1]*1976 data are actual through August and do not include September. Hence, the float trip use figures probably slightly understate the total seasonal use.*

with concessionaires who were trying to get their allocations increased.

The same supply-demand relation exists under USFS jurisdiction. Unlike the NPS case, however, the USFS has not regulated supply as directly, and permittees have not increased price because there is the possibility of adding additional trips. Price has stayed constant at $15 per person (group and age discounts excluded). Commercial use has increased at an average annual rate of 24.8 percent (table 2). Figure 2 graphically portrays the USFS supply-demand relation; output moves from Q_2 to Q_3 as demand shifts from D_2D_2 to D_3D_3 while price remains constant. Because daylight hours, limit the number of trips, one would predict price increases and a change in the supply curve similar to the condition found in figure 1.

The important differences between the market conditions portrayed in figures 1 and 2 are partially the result of different approaches to regulating market structure by the NPS and USFS. Moreover, demand shifts and demand's responsiveness to price signals demonstrated that demand is not a synonym for user days; it has a price and a quantity dimension. Both dimensions of demand must be recognized by the regulating agency. Decisions in one jurisdiction have an impact on visitor use in another.

Cross Jurisdictional Aspects of Regulation

Where price is one of the conduct options regulated by the NPS and USFS and there is the additional possibility of establishing limits on supply, there may be a potential shift in consumption from one jurisdiction to another. Put another way, regulations affecting structure and conduct may shift from the NPS jurisdiction to the USFS jurisdiction. The important issue is to what extent are substitutes available.

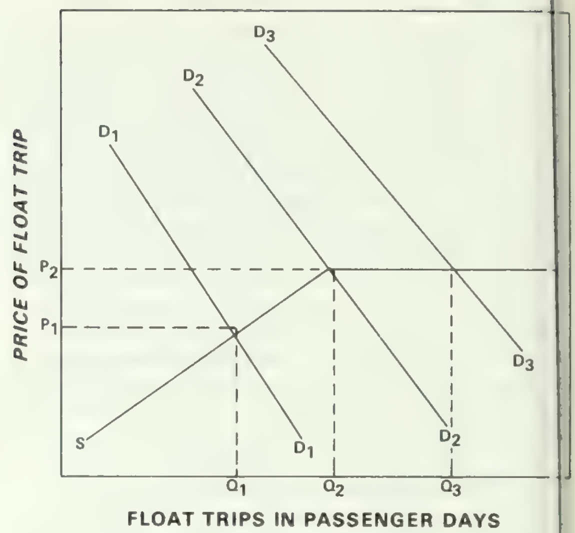

Figure 2.--*Impact of constant price on t supply of float trips.*

The economic concept of cross-elasticity of demand comes into pla If the products are substitutes that fact and the intensity of substitution can be measured by a ratio of the change in the quantity demand of one product to the change in price of another commodity unde consideration. The formula for cross-elasticity is:

$$\Theta xy = \frac{\Delta\ x \div x}{\Delta\ y \div y}$$

Where: Θxy is the cross-elasticity of th change in the quantity of x demanded with respect to the price of y; x is the quant ty of commercial trips in the Snake River Canyon; and y is the price of commercial trips in Grand Teton National Park.

The result of this calculation will tell us when commodities are substitutes for each other, in which case the

Table 2.--*Number of floaters on the Snake River in Targhee National Forest, 1973-1976*[1]

Year	Commercial trips	Commercial customers	Boatmen	Private floaters	Total use	Commercial	Private
	Number					Percent	
1973	2044	21,061	2070	3081	26,212	89	11
1974	2320	24,090	2453	3919	30,462	87	13
1975	3204	35,289	3399	4888	43,576	89	11
1976	3717	40,935	3943	6012	50,890	88	12

[1] *1976 data are actual through August and do not include September. Hence, the float trip use figures probably slightly understate the total seasonal use.*

cross-elasticity will be positive and greater then 1; or complements to one another, in which case the cross-elasticity will be negative. Two calculations have been accomplished. One is at the aggregate level involving an average price and total river use. The second is the change in quantity demanded for one firm vis-a-vis the change in price for that firm where the firm in question operated under both jurisdictions.

The results show that the float trip experience under USFS jurisdiction is a substitute for the float trip under NPS jurisdiction. User limits and price increases under NPS jurisdiction have resulted in a shift to the consumption of river trips under the USFS jurisdiction. The cross-elasticity of demand is calculated at 1.14. That is the average percent increase in quantity demanded under USFS jurisdiction was divided by the average percent change in price of the float trips under NPS jurisdiction.

A second calculation is even more dramatic evidence of the substitute nature of the two float trip experiences. One firm operates under both jurisdictions and acts as the price leader in each jurisdiction. That is, the firm is a major competitor in both areas where decisions regarding the float trip price have been followed by other competitors in the past. The cross-elasticity of demand for this firm's products is 1.80. Therefore, the price increase under the NPS jurisdiction has shifted the consumption to the USFS jurisdiction substitute.

The motivation for price change may have been profits. The marginal profit for the USFS trip was greater than that under NPS jurisdiction; hence, the price shift could have been motivated by the knowledge that in equating the marginal profit rates total profits would be increased. Undoubtably, there was some gut feel for the above; however, the principal motivation was probably the relative capacity constraints between the two jurisdictions and the greater competitive pressure under the USFS jurisdiction due to potential excess capacity. It is clear that in this case and with other possible substitute and complement situations, policies affecting the economic behavior of firms under regulation of different or the same jurisdictions can have impact other than that which is directly intended.

CONCLUSION

As visitor use reaches the environmental carrying capacity of various scenic and white water river systems, the economic consequence of various resource agency regulations will become increasingly important. Where significant regulation of economic activity occurs as the consequence of environmental planning, the results of that regulation may affect demand and resource use in other jurisdictions and in ways not specifically expected. Resource agencies that regulate commercial activities are not significantly different from the traditional regulatory agencies. Agencies, such as the NPS and USFS, must recognize and predict the effect of their regulatory actions as surrogates for the normal competitive constraints of the market process.

Several cases have appeared in the courts, and other groups have sought the assistance of members of the House and Senate where resource management policies in general and river management plans in particular have affected economic activity. Research has shown that many river systems offer multi-million-dollar opportunities to those who have permits or contracts to use the resource. Individuals have earned in excess of $20,000 per month operating float trip businesses. Profits approaching 60 percent of sales (before taxes) have been reported. The average profit rate of concessionaires and permittees under three different jurisdictions is four-to-five times greater than the average profit rate for United States industry. All these factors will cause increased awareness and scrutiny of those USFS and NPS regulations that have economic consequences. As a result, there will be a need to develop more reliable and unbiased approaches to managing resources of obvious economic value.

A MARKOV-BASED LINEAR PROGRAMMING MODEL OF TRAVEL IN THE BOUNDARY WATERS CANOE AREA

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ABSTRACT.--Describes and illustrates a Markov-based linear programming method used for predicting and analyzing travel in the Boundary Waters Canoe Area (BWCA) so management can control the rate of entry of travellers into the area.

The BWCA is a roadless wilderness area preserved under the Wilderness Act of 1964--an area of 1,062,000 acres, 18 percent of which is covered by water. There are 1,076 lakes at least 10 acres in size which are interconnected by a network of streams, portages, and ponds comprising more than 1,200 miles of canoe routes. Adjacent, and to the north, is the Quetico Provincial Park in Canada, a similar but slightly larger area.

The BWCA has been the object of political controversy since 1902 when 500,000 acres of public domain land was set aside. There have been struggles over road building, recreational development, logging, dam building and power development, aviation and mining. Currently, logging and mining suits are under litigation.

One of the more disturbing threats to the BWCA is the recent increased demand for outdoor recreation. Since 1969, the use of the BWCA has increased by 54 percent; over a million visitor days[1] during 1974. This use might not be excessive if it were more evenly distributed over space and time, but it occurs principally along certain routes and at peak periods. For example, there [are] 70 designated entry locations, but 20 percent of all groups in 1974 entered through one (Moose Lake). Ten entries account for more than 70 percent of all use.

This has led to concern both for the recreationists' impact on the integrity of the wilderness ecology and for the detrimental effects such high levels of use have on the quality of the recreational experience. Research has shown that a significantly larger number of people could use the area with less ecological damage and higher levels of satisfaction if the use were more evenly spread. This prompted the Forest Service to adopt a management program for the 1976 season which restrict[s] the number of entrants at entry points and required advance reservations. This program was conceived in part because of a better understanding of recreationists' travel behavior due to the development of the model described in this paper. The Ontario Ministry of Natural Resources is considering a similar program for the Quetico Provincial Park.

Development of BWCA Research

In cooperation with the North Central Forest Experiment Station, research was started at Northwestern University in 1970

[1]*One visitor day is equivalent to one individual spending 12 hours within the recreational area.*

ts purpose was to explore methods for pre-icting travel. Initial studies showed hat Markov-renewal theory was promising Gilbert 1972, Gilbert *et al.* 1972)[2]. Sub-equent empirical studies demonstrated that he simpler Markov chain provides an adequate ragmatic model (Wojno 1973, Wang 1976, Wang, eterson, and deBettencourt 1976).

Based on travel diaries collected in 971 and in 1974, three generations of nalysis have been completed. The first as a pilot study of a system of lakes near he end of the Gunflint trail. Based on he results of this, the Forest Service ommissioned an operational model of the BWCA's most heavily used area near Ely, Minnesota. This was expanded to cover the ntire BWCA and the Quetico Provincial Park. The BWCA was subdivided into 69 interior zones and 33 entry zones, and the Quetico into 6 zones to describe the interaction of travel between the United States and Canada (fig. 1). The travel model now being used was developed for two seasons and three travel modes.

[2] *A mathematical framework that describes a certain kind of stochastic (probabilistic) process (Cinlar 1975).*

Sixty-seven percent of campers in the BWCA travel by water. Paddle canoes, which is the dominant mode of travel, has accounted for most of the growth during recent years. Thus, it is the principal object for analysis and control. Separate models have been constructed for travel by motor canoe and motor boat. The modes behave differently because of legal and physical restrictions. Spring and early-summer travel behave differently from summer-fall travel; consequently, the canoeing season has been divided into two time periods. Thus, there are actually six separate models, one for each of two seasons and three travel modes. It is mathematically feasible to combine the three modes (Wang, Peterson, and deBettencourt 1976), but this has not been done operationally. The models do not deal with day use because it accounts for only 10 to 15 percent of total use.

The data base obtained in 1971 was roughly a 35 percent sample of all travel. For example, records were obtained from 4,720 paddle canoe groups. These groups spent 19,599 nights camped at 471 different lakes in the BWCA and Quetico. The "average" group spent 1.6 nights at each of 2.6 lakes and remained 4.2 nights in the wilderness.

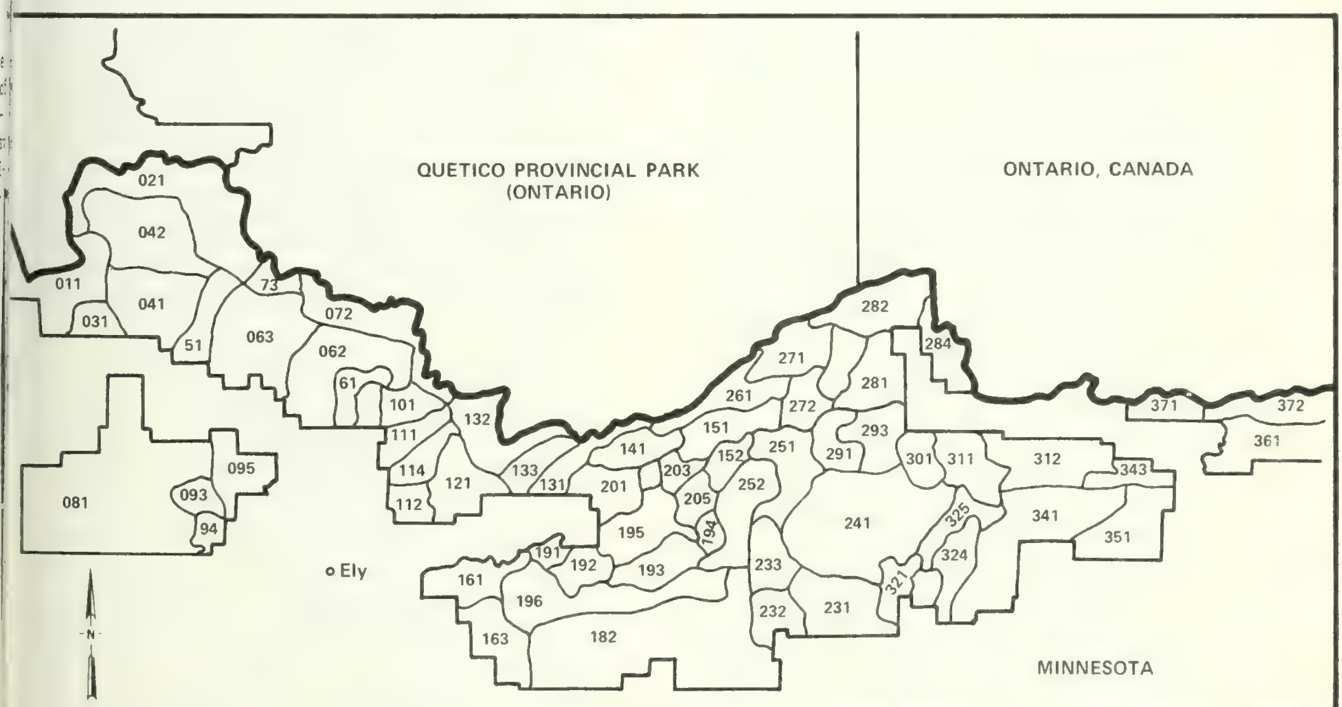

Figure 1.--*Interior travel zones in the Boundary Waters Canoe Area as used in the Markov analysis.*

The 1971 data base was used by Wang (1976) to ascertain the validity of the Markov chain approach before the operational models were developed. Although he found that the theory didn't explain the data perfectly, predictions based on steady-state expectations for 30-day periods were remarkably correct. The Forest Service used these predictions as "bench marks", or reference points, for the development of entry point quotas.

Because the analytical framework of Markov theory can be used, the travel models can be constructed directly for solution of systems of linear equations as opposed to the vastly more complex and expensive simulation approach. The programs have been developed for online use and are easy to operate. Forest managers having relatively little training in mathematics or computers can learn to use the system in a few hours. Thus, it is possible for the manager to do his own analysis of alternative management policies.

The Markov framework allows for the development of two distinctly differently modes of analysis, what we call "forward-seeking" and "backward-seeking" models. In the forward-seeking approach, the manager specifies judgmentally the entry rates for each entry point. These rates are specified as daily averages for a 30-day period. The model is then used to calculate the expected (average) number of visits each zone would receive under this entry policy. The visits are then compared with carrying capacities, also specified by the Forest Service. If, in the manager's judgment, the expected number of visits are not in line with the carrying capacities, he goes back and revises his entry policy judgmentally. Thus, it is a trial-and-error process of 1) specifying entry rates, 2) calculating numbers of visits received by zones, 3) comparing visits with capacities, and 4) revising entry policy.

In the backward-seeking mode, the manager is asked to specify carrying capacities for each of the interior zones--and upper and lower limits for each of the entry points. The upper limits are determined by the physical capacity of the entrance, and the lower limits are generally based on a consideration of the feasibility and implications of radically cutting back on use at existing entry points. Subject to these constraints, a linear programming algorithm then is used to maximize the total number of groups entering the BWCA, expressed as the sum of the numbers enterin through each entry point. The solution o this linear programming problem specifies the "optimum" entering rate for each entr given the carrying capacities, entry restrictions, and the Markov equations describing the travel process.

Thus, in the backward-seeking method the manager gives restrictions and solves for entry policy. The linear program als gives "opportunity costs" for each of the constraints. This information leads the manager to a reexamination of the carryin capacities and restrictions he has specif d, and a decision about their applicability and utility. The backward-seeking method uses the MPOS-MPOSONLINE system developed at Northwestern University's Vogelback Co puting Center (Cohen and Stern 1974). Th system can be used online, and the models allow the carrying capacities and entry r strictions to be edited interactively.

Mathematical Structure of the Model

The travel model is formulated in terms of three different kinds of zones o states that a camper might occupy: entry zones, interior zones, and exit zones. T entry zone is the access point through wh the camper enters the BWCA. Let z_{ki} be t probability that a camper at entry zone k will spend his first night camped in interior zone i. These are the entry probabilities and comprise a matrix Z. Both t probability of going from one entry zone to another and the probability of going from an entry zone to an exit zone are defined as zero.

Let q_{ij} be the probability that a traveller camped in interior zone i one night will occupy interior zone j the next night. The probability of going from an interior zone to an entry zone is defined as zero, and the q_{ij} do not include the probabilities of going from interior zones to exit zones. Let x_{im} be the probability that a camper occupying interior zone i one night will be found in exit zone m the next night. Once a camper enters an exit zone, he is absorbed; that is, the probability of going from an exit zone to an interior or entry zone is defined as zero. The exit zones may correspond geographical with the entry zones, but they are defined

s different zones for mathematical purposes. Indeed, there is only one exit state in the model because exit points were not identified in the 1971 travel diaries.

The q_{ij} probabilities comprise a matrix Q. They also comprise the basis for a Markov chain if it is assumed that the probability q_{ij} is dependent only on the zone occupied, zone i, and is independent of the history by which the traveller arrived at zone i or how long he has been there.

If these and other assumptions are satisfied (Cinlar 1975), the expected number of visits received by each interior zone is given by

$$(V) = [Z(I - Q)^{-1}]'E, \qquad \text{[Eq. 1]}$$

where

(V) is the vector of expected or average number of visits received by each interior zone after all travellers have exited from the system,

E is the vector of the number of groups at each intry point at the beginning of the process, and

Z and Q are the matrices of entry probabilities and interior transition probabilities as defined above.

The exit probabilities, x_{im}, do not enter the calculations directly.

Equation [1] also is true for a steady-state process with constant or stationary daily entry rates over a given time period, say 30 days, where E is defined as the number of entries over a 30-day period and V is the expected number of visits to interior zones over the same period.

Equation [1] actually is a system of simultaneous linear equations and is the basis for the forward- and backward-seeking methods of analysis. In the forward-seeking analysis, E, the entry policy, is prescribed by forest management, and the equations are solved for V, the visits received by interior zones. In the backward-seeking analysis, upper limits are specified for V (interior zone carrying capacities) and, by means of linear programming, E is maximized, subject to these carrying capacities and to the upper and lower bounds placed on the individual entry locations.

Validity of Underlying Assumptions

Equation [1] is valid only if the underlying assumptions of Markov theory are correct and can be applied to the travel process. Potential sources of trouble in this regard include:

1. Dependence of the probability q_{ij} on the history by which a traveller arrives at zone i,
2. Noninformational probabilities that are arbitrary and not predictable,
3. Nonstationary probabilities, i.e., probabilities that change over time,
4. Nongeometric renewal processes,
5. Congestion feedback,
6. Nonstationary entry rates,
7. Heterogeneous population of travellers.

Dependence of q_{ij} on prior States

If the probability, q_{ij}, is dependent upon the route by which a traveller has arrived at zone i, Markov theory will not correctly represent the process. Mathematically, this can be overcome by redefining the states as sequences of states, such that independence is achieved. However, in a network as complicated as the BWCA, this is not practical.

There is a strong tendency in the BWCA for canoeists to exit by the same point through which they entered. This occurs because they have left their cars at the entry point and/or the canoe base where they rented and must return the equipment is at a fixed location. Outfitters will make deliveries and pickups at different locations, but there generally is a significant additional charge if much distance is involved. This problem could be overcome simply by constructing separate models for each entry point and adding the results. This would be more expensive, but it is practical if necessary and if adequate data are available. However, in the BWCA there is another tendency that largely nullifies the problem. The heavily used entry points

tend to serve exclusive interior regions. Areas of overlap that could cause errors are generally in the most lightly used zones. The heavily used interior zones tend to be dominated by single-entry points. Thus, the system tends to behave as a set of geographically separate processes by entry point.

In any case, errors creep in only if proportional entry rates are changed significantly from the conditions under which the data were collected. In other words, problems could occur if one entry point is doubled and another halved, and if these entries serve overlapping regions. There are political pressures, however, that strongly tend to discourage policies that depart radically from the status quo. Because of these tendencies, the model gives pragmatically useful predictions, although the assumption is not strictly satisfied. Although the errors are theoretically important, they tend to be of little practical significance.

Noninformational Probabilities

If travel in the BWCA is whimsical and arbitrary and not determined or biased by fixed properties of the area, there is little point in this type of analysis. The travel simply would not be predictable. However, our research has shown that the probabilities are informational. Travel is influenced strongly by physical characteristics of the network of lakes; most significantly by accessibility (distance and numbers and difficulty of portages). People entering the system tend to be channeled into predictable routes. Although the behavior of an individual party does not appear to be predictable, aggregate probabilities are stable. Statistically speaking, the observed probabilities could not have been sampled from an arbitrary and unpredictable process.

This was verified by data collected at one entry point in 1974, which was essentially similar to the travel originally observed in 1971.

The model is strictly descriptive as it is formulated. If something that helps to determine travel behavior is changed, the probabilities will change, and the model will have to be recalibrated--unless an explanation of the probabilities is available that will allow them to be repredicted from theory. If the Forest Service were make radical modifications in the diffic of selected portages, for example, this could alter the probabilities.

Nonstationary Probabilities

If the probabilities were to vary o time, either in a cyclical way by season or in a systematic drift from year to ye Markov theory would not be applicable wi out modification. Seasonal variation th has been observed in the BWCA, is accommodated by calibration of two models, on for spring, and one for summer.

Annual drift could be caused by systematic changes in the kinds of people coming to the BWCA. It could also be cau by changes in the route recommendations made to customers by outfitters. It is n clear as yet how stable the BWCA probabilities are over time, but the data collected in 1974 at one entry point agre very well with data collected in 1971. A great deal of inertia is indicated in the system; if changes are occurring, they ar occurring very slowly and by small increments. In any case, a program of periodic maintenance should be pursued.

Nongeometric Renewal Process

In the simple Markov chain, q_{ii}, the probability that a group camped in zone i will be found there the next night, is constant for zone i, no matter how long the group has already been camped there. The data have demonstrated this to be tru for most of the lakes in the BWCA and Can, although a few heavily used peripheral lakes and several destination lakes do violate the assumption. The majority of zones show geometric renewal processes, although zones containing several lakes o dominated by a large nongeometric lake ar troublesome. The Markov-renewal theory can be used to show that the expected number of visits received by a zone over a time interval is not affected by the natur of the renewal process--if the time interv is sufficiently long.

Congestion Feedback

If the probability, q_{ij}, is dependent upon the number of travellers occupying zone i or zone j, Markov theory is not valid. This question hasn't been tested

igorously, but there is reason to suspect hat canoeists will not modify their camping ocations significantly in response to enountered congestion. They may make longun changes in behavior; that is, they may hoose a different route on their next rip, or they simply may not go back. In he short run, however, there is not much hey can do that would affect the aggregate ehavior in the area. A group may push on ne or two portages, but canoeists generally o not begin looking for campsites until hey have gone about as far that day as they eel able or willing. When congestion is ncountered, a group is most likely to cout the lake in question until a campsite s found or accept a nondesignated site. f they do move on, they will not go far efore stopping; thus, they probably will till be in the same travel zone.

onstationary Entry Rates

The model is set up to be descriptive f a batch or steady-state process. If he demand process is erratic or cyclical, he zone populations will also be erratic. he long-term expectations will still averge out and be correct, but predictions of aily populations (something not attempted y the model) will be invalid. An imporant question from the management point of iew is whether, or for how long, precribed quotas for entry points can be xceeded without violating interior carrying apacities following a period of low demand t one or more entry points. Our recomendation is conservative: that the benchark quotas be respected whether or not uotas on previous days have been filled. he model is not designed to answer quesions about the dynamic response of the ystem. This would require a more elabrate (and expensive) dynamic formulation f the model or abandonment of the analytcal approach in favor of simulation. ither decision would rule out backwardeeking analysis.

The quotas derived from analysis provide a benchmark or frame of reference for policy decisions and should not be regarded as prescribing decisions or substituting for good judgment. There are certain problems, like the dynamic and nonstationary behavior of the system, that simply are not addressed by the model.

Heterogeneous Population of Travellers

If two or more different Markov processes, each with unique probabilities, are mixed, predictions of the expected number of visits received by the states or zones in the system under batch or steady-state conditions are correct when the proportional mix of the populations is held constant. Under these circumstances, the observed probability, q_{ij}', is a weighted average of the true probabilities of the several populations. If the proportional mix of the populations is changed significantly, that weighted average will change, and the resulting predictions will change.

There are mixed populations in the BWCA. For example, travel mode (paddle canoe vs. motor canoe vs. motor boat) strongly changes travel behavior. These three modes cannot be mixed unless the proportional mix at each entry point is held constant. However, the Forest Service was interested in separate predictions for the three modes, so they were separated in the model and analyzed separately. The two seasons, spring and summer, were also separated. This was done, because it was found that the behavior was different, and the populations had to be analyzed separately.

If there are other problems of mixed populations, say within the paddle canoe group, they will not be troublesome as long as the proportional mix does not change significantly. One potential problem is that outfitters may be biasing the routes of their clients differently by means of the advice they give. We expect, however, that these effects are sufficiently randomized.

The important question is not whether Markov theory is a strict theoretical explanation of travel in the BWCA. The important question is whether and under what circumstances the model based on Markov theory is a useful tool for management purposes. We must frankly state that Markov theory may not be the ideal theoretical explanation of the travel. At best, it is a reasonably valid approximation of some aspects of the travel. The data speaks for itself. In 1974, the Superior National Forest collected a sample of about 300 travel diaries from the Lake One entry point (August). The model based on 1971

data was used to predict the expected number of visits received by the Lake One system of interior zones as a function of the actual number of groups entering at that location. The correlation between predicted visits and actual visits was 0.96, which gives an estimated reliability of 92 percent. Thus, when used properly, the indications are that the model gives very good information. However, it is very important to understand the limits under which the predictions are valid and to recognize that the model is a generator of information and not a maker of decisions.

Areas of Needed Research.--The work to date has identified the following areas where further research is needed.

1. Model validation
2. Monitoring change and evaluation of temporal stability
3. Temporal maintenance of models
4. Better and more current data base
5. Improvement of operational characteristics of existing models
6. Basic research to improve the model framework
7. Use of the models in educational gaming seminars to familiarize and train Superior National Forest personnel
8. Generalization of the approach to other situations and problem areas.

Validation.--Existing data are not adequate to allow thorough validation of the models. Whereas the evidence we have seen from available data as well as from conceptual and theoretical reasoning has made us confident that the models produce valid and useful information, the question needs to be examined more rigorously. We have tested and demonstrated that 1) the travel process is nonrandom (i.e., predicatable), 2) temporal homogeneity can be effectively achieved by partitioning the data into two or three seasons, 3) population homogeneity can be achieved by partitioning by travel mode, 4) the 1971 data comply reasonably well with the Markov assumption, and 5) the models do an excellent job of replicating the 1971 behavior (Wang 1976).

However, weaknesses in the 1971 data prevent us from testing rigorously whether the process must be separated by entry point. The indications are that this is not necessary when evaluated by pragmati criteria, but in order to be conclusive, new data are required.

We are unable to give the model a rigorous test for subsequent years, beca e the travel permit data are not adequate. Validation done with a small set of obse vations collected at entry 30 in 1974 is very favorable, but not conclusive for t entire model package. For proper valida on, we need a whole new data set. The data should include point of entry, point of exit, and a day-to-day record of the cam site location by lake, or in the case of large lakes, by location within the lake The record should also include the usual travel permit data on party size, travel mode, etc.

Monitoring Change.--Whether or not the models are valid and whether or not the travel behavior has not been changing since 1971, control programs imposed in t future probably will change travel patte . This should be monitored so that the eff iveness of the controls can be evaluated The monitoring should be done through ca fully designed smaples on a continuing basis. Such samples will not only revea changes, if any; they will also provide a continuing and cumulative framework for model validation and maintenance.

Model Maintenance.--Any model that used as a source of information for plann g needs to be maintained through periodic recalibration and validation. This needs to be done.

Better Data Base.--We have discovered ways that the 1971 data set might have be improved. Various weaknesses in the way those data were collected impose limitati s on what can be done with the models. For example, it is important from a managemen point of view to differentiate among Basswood Lake, Basswood River, and Crooked Lake. In the coding process, Basswood River was coded as Crooked Lake, and we a unable to differentiate. It is also desirable to differentiate among zones with large lakes like Crooked, La Croix, and Basswood. Also, in the 1971 data set, th e were problems that made it difficult to determine the entry point for most of the travel diaries. This occurred because th

ravel permit, which contained entry point, as separated from the travel diary, which id not contain entry point, and not enough f them ever got back together again.

These and other weaknesses suggest hat a freshly designed data base would reatly magnify the usefulness of the models. hus, we need the new data set and the reources with which to reconstruct new odels.

Improvement of Operational Characterstics.--Each of the generations of model onstruction has revealed ways that the job ight have been done better. New questions rise that were not anticipated, weaknesses re revealed that had not been noticed earlier, new capabilities are discovered, new insights emerge.

We need to sit down with the Forest ervice in a series of applications sessions here we apply the model, dissect it, learn ore about what it can and can't do, and earn more about the questions the Forest ervice needs to have answered. This should e done, however, after we have all gained pplied experience with using the current odels. This could be accomplished in a elatively short time by means of some inensive sessions. Out of such sessions ould emerge beneficial reconstructions of he problem as well as the technical strucure of the model.

The following questions need to be addressed:

1. Reexamination of travel zone structure and aggregation of entry points.
2. Separation of Canada-bound travel.
3. Cooperation with Canadian concerns.
4. Refinement of the statement of questions in need of answers.
5. Identification of user difficulties.
6. Improvement of specifications for user instructions.
7. Editing improvement in output, including improved legibility.
8. More versatility of online input options (e.g., online modification of travel probabilities).
9. Increased operating efficiency, including input-output time as well as cost of computation.

Basic Research.--The following avenues of new research would be viable because 1) they would improve the performance of the models for the BWCA problem, 2) they would represent contributions to the state-of-the-art in modelling as well as in applications of Markov theories.

1. Explanation of the travel probabilities.
2. Evaluation of this approach against the wilderness simulation model developed by RFF in cooperation with the USDA Forest Service (IBM, RFF, 1973).
3. Exploration of analytical approaches to real time temporal variations in demand (i.e., "peaks and valleys").
4. Exploration of analytical and programming ways to integrate the three travel modes into simultaneous backward-seeking models for the management problem.
5. Consideration of the problem of "encounters" to determine whether it is of real concern in the BWCA problem and, if so, whether it can be dealt with effectively within the analytical framework (as opposed to simulation).
6. Exploration of the merits and potential of analytical treatment of day use in the models.

For example, the problem of explaining the travel probabilities is of importance because, if solved, it would vastly expand the versatility of the analysis in terms of the kinds of management options they are capable of responding to. It would also produce valuable insights on how to get at changing travel behavior.

By explanation of the probabilities, we mean the construction of equations that predict the magnitude of a given probability as a function of the variables to which travel decisions are sensitive. Wang (1976) showed that the travel in the BWCA is informational and nonrandom--that observed patterns of movement (i.e., the probabilities) could not have occurred by chance alone from arbitrary processes. Thus, travellers must be tending to use consistent "rules" as a basis for their movement decisions. At least, we can expect that the decison-making behavior that determines the observed travel can be described by systematic "rules." It is likely

that the movements are determined to a large extent by inherent network properties, especially accessibility factors. Preliminary investigation strongly suggests that the transition probabilities are predictable as a function of measurable properties of the travel network.

Educational Gaming Seminars.--The numerical outputs of the models are valid information about how the BWCA system would behave under real conditions. Equally important, however, is the effect of the model on the person who is using it. Management of the model by sitting down at the computer console and testing alternative management options is a simulation of management of the BWCA. Extended use of the model cultivates the same kinds of skills that would be cultivated by extended management of the BWCA. The operator learns to refine his questions. He develops better intuitive feelings for how the system behaves and the kinds of problems he is likely to encounter. In short, his ability to think about the problem is greatly enhanced. Perhaps this is more important than the direct numerical products.

CAMPSITE CHOICE BEHAVIOR IN THE RIVER SETTING: A PILOT STUDY ON THE ROGUE RIVER, OREGON

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ABSTRACT.--The relation of campsite choice to the natural characteristics of campsites was analyzed along the Wild and Scenic Rogue River in Oregon. Two regression models--for commercial and noncommercial camping parties--were formulated relating campsite choice to 13 site characteristics of river terraces. Of the 5 significant variables selected for each model, 3 were the same: size of the campsite, size of the tributary providing potable water to the location, and a rating of beach area available for landing a boat.

The recent growth in popularity of amping within the confines of river cor-idors provides a new opportunity to xamine man-environment relations associ-ted with campsite choice behavior. Such esearch may not only help to shed light n features of the environment which ttract or repel human use, but also dentify behavioral patterns of different ocial groups in the choice of campsites. nderstanding of both matters is of con-iderable importance to resource managers nd planners who are faced with decisions s to the kinds and amounts of facilities hat need to be provided. How often do arties stop along a river route and how ong do they stay? What features of the atural landscape seem to be especially ritical in the selection of a campsite nd the utilization of it? Are there mportant differences between the behavior f groups which have a licensed guide and hose which do not?

The present paper reports on an nvestigation of river travelers and the egree to which their behavior in hoosing campsites is related to natural haracteristics of the locations where amping occurs. This pilot study of amping in the river environment was nitiated in 1974 as a part of a broader research project (Pfister and Frenkel 1974, 1975). It was based upon previous research of campsite choice for auto-camping (Shafer and Thompson 1968, Lucas 1970, Lime 1971) along with recent research to improve methodology for inventorying backcountry campsites (Hendee, *et al.* 1976).

The study sought to identify (1) characteristics of specific groups of river travelers, (2) the campsite choice patterns of those specific groups of river travelers, (3) natural site charac-teristics of all river terraces serving as campsites, and (4) the relation between the number of times a campsite is chosen and selected natural characteristics of the campsite. For the latter objective, models suitable for examining the relation between the amount of use a location receives and its natural site characteristics were formulated.

STUDY AREA

The study area for this investigation is the Rogue Scenic Waterway in Oregon--a popular, free-flowing river protected under both State and Federal legislation.

Located in southwestern Oregon, the 84 miles of the river that are protected are classified by state legislation (ORS 390.805 - 390.925) into 5 river management areas: natural, scenic, recreation, natural scenic view, and river community (fig. 1).

The study area has been described in detail in the "Notice of Revised Development and Management Plans" (Federal Register 1972). Field investigations were conducted in the "Natural River Area", which begins at the confluence of Grave Creek and terminates at Watson Creek. Under Federal legislation, the identical 84 miles of the river is classified into 3 river management areas--recreational, scenic, and wild--and the study area is classified as a "Wild River Area" (PL 90-542). Numerous camping places are present along this 35-mile river segment, and a substantial number of visitors are attracted to the area each year (table 1).

Table 1.--*Visitors per year in the Rogue Scenic Waterway between Grave Creek and Watson Creek, 1973-1975*

Type of Group	1973	1974	1975	Char 1973-
	- - *Number*		- -	*Perce*
Commercial trips	3340	3714	4000	+ 20
Noncommercial trips	1002	1718	2520	+151
Hikers	809	1236	1500	+ 85
Total	5151	6663	8020	+ 56

River terraces as camping locations were selected for in-depth study since, excluding lodge accommodations, they offered the only level areas available for camping within the study area. In this study, a river terrace refers to any topographic bench along a river formed by fluvial or mass-wasting processes. Normally, a "terrace" indicates former flood plains formed at different stages of erosion or deposition. However

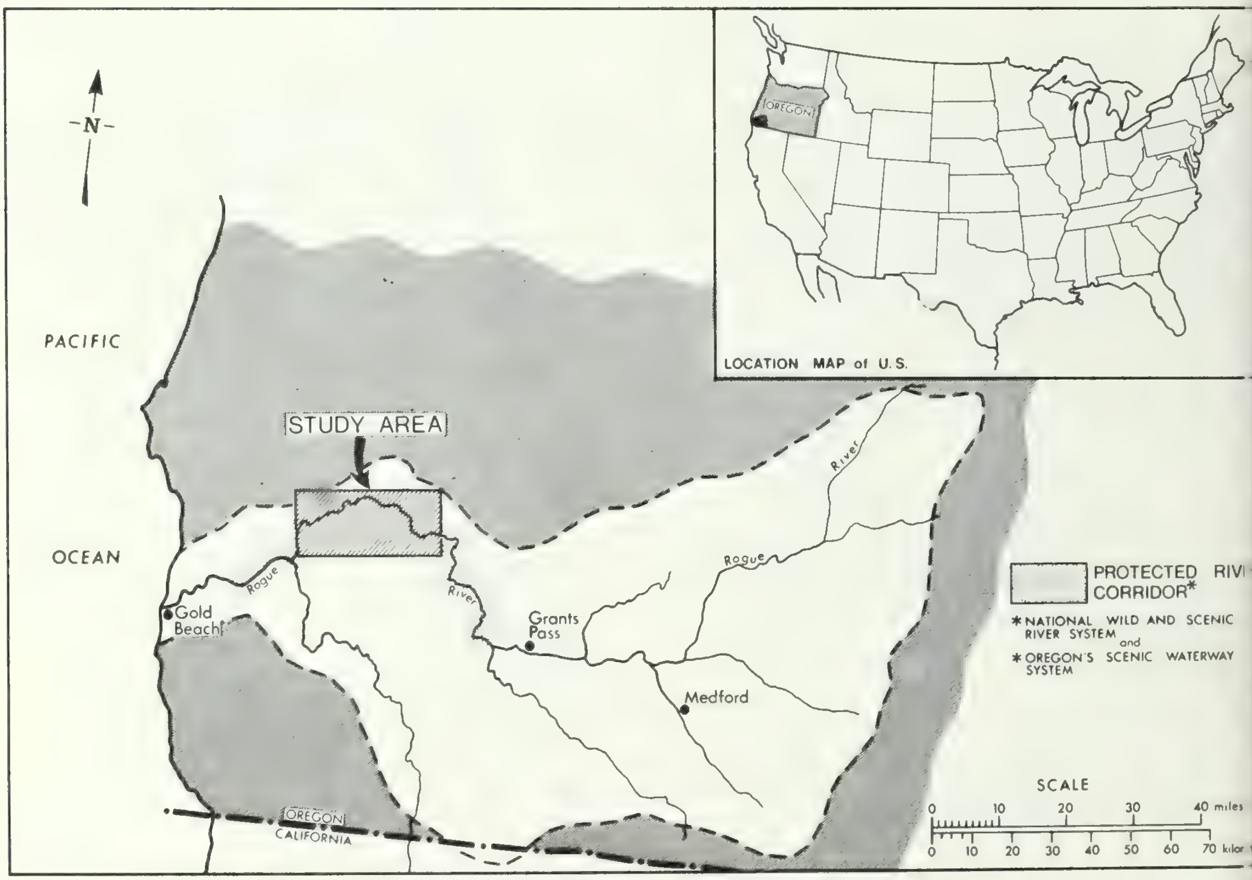

Figure 1.--*Location of the Rogue River drainage basin, the protected river corridor, and the study.*

mass-wasting appeared to predominate in the formation of several high bench areas in the study area and the definition was expanded to include them. Most terraces exist as unvegetated sand bars associated with fluvial processes while some higher terraces may exhibit soil development and forest vegetation cover. Undoubtedly river terraces are one of the most common fluvial features of the riparian environment and are commonly used for camping in other free-flowing rivers protected under State or Federal legislation in the western United States (fig. 2).

STUDY DESIGN

All camping parties had to travel past all of the river terraces in the same direction and had the opportunity to respond to each campsite in the same sequence. In addition, it was known that all river travelers began their trip at some point east of the study area boundary and were unable to exit the river corridor until passing the western boundary of the study area. Previous investigations of campsite choice behavior were unable to control such factors. Few research settings can provide such valuable natural means of obtaining control over the movement of a camping population than those associated with a river corridor.

Sample Unit

The sample unit was a camping party traveling in the study area during the summer of 1974 (July 1 to September 2). (A camping party was defined as a social group that travels together in boats for the purpose of engaging in a variety of recreational behaviors of which camping in the open air was but one type.) Groups

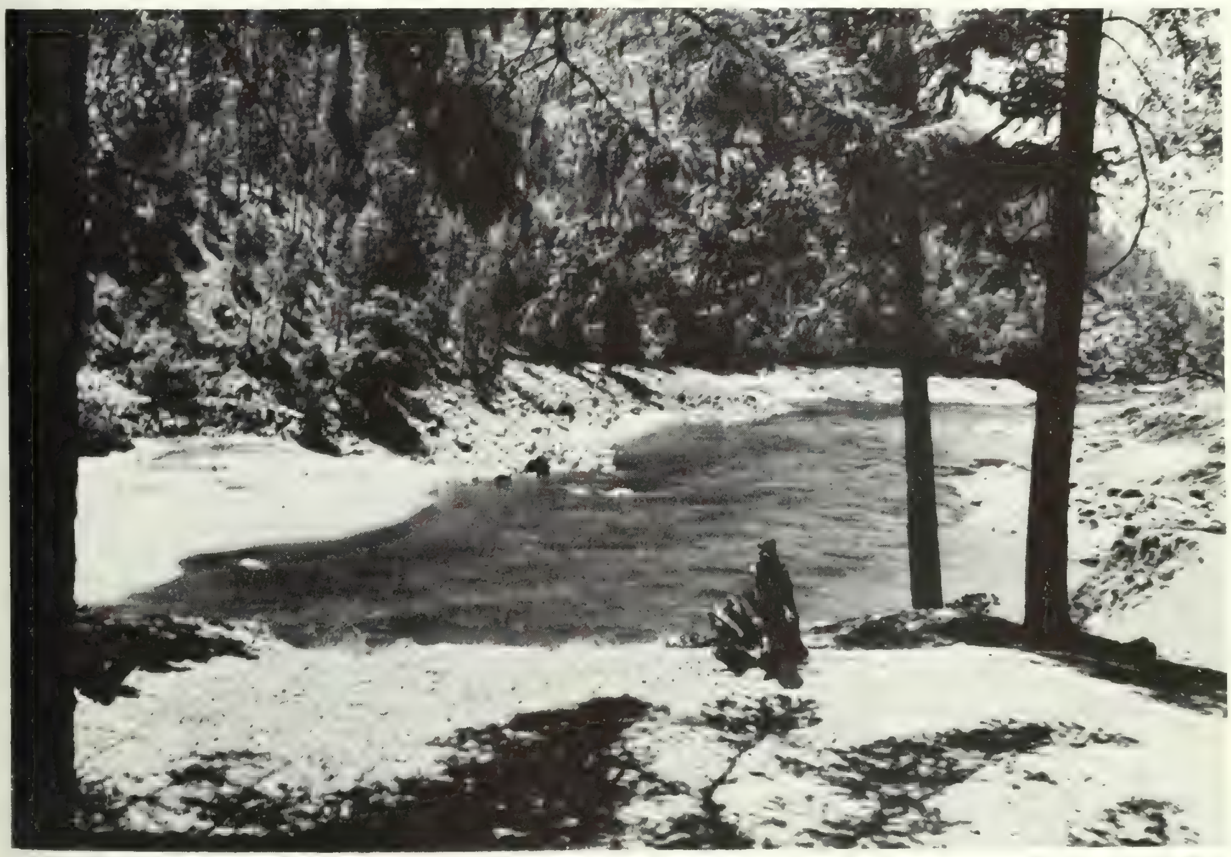

Figure 2.--*View from high terrace looking down the river corridor with low sand terrace (left middle) on opposite shore.*

were further classified as either: (1) Commercial--those groups where a fee, charge, or other compensation was collected by a guide or outfitter for services rendered and where individuals traveled in a boat licensed for hire, or (2) Noncommercial--those groups not part of any profit-making operation and where individuals traveled in privately owned boats. The commercial groups have a long history of use on the river and such use is identifiable through records on the number of licensed outfitters offering commercial river trips. Noncommercial use is a more recent category of river travel. It appears to be increasing rapidly and, in 1974, was not controlled by agencies managing the river.

To assure that seasonal variation in camping parties was taken into account, 57 percent of all possible days were sampled (36 days out of 63 days) between July 1 and September 2, 1974. The sample days were drawn at random within two strata--weekdays and weekends. The number of days sampled within each strata were proportionately equivalent to the total days possible for each strata.

Data were obtained from one member of each camping party upon their departure from the study area. The respondent was randomly selected from each party since his response to selected attitudinal questions was needed as part of another research endeavor. A self-administered questionnaire and a daily log sheet were utilized to collect data concerning (1) Population characteristics--commercial or noncommercial, (2) Party characteristics--size, length of stay, type of boats used, number and location of river terraces used for camping, and (3) Personal characteristics of the respondent--socio-economic, attitudes towards crowding and management controls.

River Terraces

Little information was available which located or described the river terraces within the study area. Several place names for terraces were only known by local outfitters and the names did not appear on published maps of the area. Numerous common terms were often used to refer to what has been defined herein as a river terrace and common descriptive attributes of the terraces had not been evaluated. From two field reconnaissanc trips, a list of onsite characteristics was formulated. Additionally, some rive landscape variables were considered as identified in the literature (Craighead and Craighead 1962, Leopold 1969b, Morisawa and Murie 1969, Dearinger 1968, Dearinger *et al.* 1973). Twenty-four prospective site characteristics were placed upon a standardized form and a pilot test conducted to evaluate terrace within the study area. Thirteen characteristics were observed to be present at all the terraces and appeared to be readily measureable by a team of 2 researchers. These 13 site characteristics were retained as measurements applicable to the river terraces within the study area and a description of field procedures has been reported by Pfister and Frenkel (1974). The site characteristics were as follows: (1) Campsite area, (2) Distance to potable water, (3) Tributary size, (4) Amount of area unvegetated, (5) Amount of A.M. shade, (6) Amount of P.M. shade, (7) Boat landing, (8) Accessibility of terrace, (9) Visibility of terrace, (10) Amount of firewood, (11) Wind protection, (12) Interna seclusion, and (13) External seclusion.

ANALYSIS

Forty-seven parties were interviewe from the commercial camping population--44 percent of the total population. Eighty-eight parties or 47 percent of th noncommercial camping population were interviewed. Nonresponse to the questio concerning campsites chosen occurred in 11 and 4 percent of commercial and noncommercial parties, respectively.

Frequency tabulations were compiled in order to analyze (1) the characteristics of camping parties and (2) their campsite choice patterns. The research hypothesis of this investigation--suggesting that a significant relation exists between the amount of camping occurring at river terraces and selected characteri tics of those river terraces--was tested utilizing linear regression analysis.

Characteristics of Camping Parties

Party size ranged from 2 to 25 people nd commercial parties were substantially arger than noncommercial parties. eventy-five percent of the commercial arties ranged from 16 to 25 people while nly 13 percent of noncommercial parties onsisted of that many people (table 2).

Table 2.--*Commercial and noncommercial groups in camping parties of various sizes*

(In percent)

	People in Party				
	1-5	6-10	11-15	16-20	21-25
Commercial N=47	5	10	10	35	40
Noncommercial N=85	33	37	17	8	5

Most commercial camping parties raveled by inflatable rafts; only 10 perent used any other type of boat. In conrast, noncommercial camping parties were ot as specialized as to type of boat sed in that inflatable kayaks and hardhell boats (drift boats and fiberglass ayaks) were used almost as frequently as nflatable rafts (47 percent versus 53 ercent of the time respectively) (table).

Table 3.--*Commercial and noncommercial groups traveling in various types of boats*

(In percent)

	Drift Boat	Inflatable Raft	Inflatable Kayak	Hardshell Kayak
Commercial N=47	10	90	0	0
Noncommercial N=85	31	53	8	8

A difference between the camping rties concerning the length of their rip is evident when one examines those rties spending 3 to 5 days in the area. n this regard, commercial parties tended o spend more trips of 3- and 4-night ration in the area than did noncommerial (56 percent versus 29 percent spectively) (table 4).

Campsite Choice Patterns

Although the commercial parties ent more 3- and 4-night camping trips thin the study area, they limited their

Table 4.--*Commercial and noncommercial groups by the number of nights they stayed within the study area*

(In percent)

	Nights				
	1	2	3	4	5
Commercial N=42	7	37	33	23	-
Noncommercial N=82	16	54	26	3	1

choices to 26 of 48 locations identified by both parties. In contrast, the noncommercial camping parties, tending to have trips of shorter duration, chose campsites along the entire river corridor occupying 45 out of the 48 locations identified by both parties. From this observation, it seems apparent that the commercial camping party has a more concentrated or clustered choice pattern than does the noncommercial party. This difference is examined further in regards to the results of the hypothesis tested.

Research Hypothesis

Stepwise multiple linear regression analysis was employed to test if significant relations exist between PARTY-NIGHTS (Y) and site characteristics (X's) of the river terraces where camping occurs. The variable, PARTY-NIGHTS, refers to the number of times each campsite was chosen by a camping party. Two regression equations, herein referred to as models, were formulated for relating commercial and noncommercial campsite choice to river terrace characteristics. Multiple regression analysis (Nie, *et al.* 1975) indicated that five variables were statistically significant in describing the variation in PARTY-NIGHTS for each model (tables 5 and 6).

The best model for explaining the variation among party-nights for commercial campers is:

$$Y = 7.7986 + 0.5439\ X_1 + 2.441\ X_2 + 0.5703\ X_3 + 0.6387\ X_4 + 0.8095\ X_5$$

where: X_1 = the square feet of open area at each terrace (AREASIZE); X_2 = average channel size in square inches of the tributary providing potable water at

Table 5.--*Summary of stepwise regression model for commercial camping parties*

Step	Variable	Standard Error	R^2	Increase	t-Value entering	Degrees of freedom
1	TRIBDEX	5.9515	0.6160	0.6160	[1]6.2055	25
2	WINDPRO	4.7186	0.7087	0.0927	[1]2.7058	24
3	BOATLAND	4.1390	0.7556	0.0469	[2]2.0594	23
4	EX-SECLU	3.8718	0.7818	0.0262	[2]1.5869	22
5	AREASIZE	3.6810	0.8024	0.0206	[2]1.4451	21

[1]Significant beyond the 0.01 level.
[2]Significant beyond the 0.1 level.

Table 6.--*Summary of stepwise regression model for noncommercial camping parties*

Step	Variable	Standard Error	R^2	Increase	t-Value entering	Degrees of freedom
1	AREASIZE	16.7911	0.2598	0.2598	[1]3.8397	42
2	BOATLAND	16.0042	0.3113	0.0515	[2]1.7507	41
3	TRIBDEX	15.0913	0.3664	0.0551	[2]1.8655	40
4	PM-SHADE	14.4426	0.4088	0.0424	[2]1.6722	39
5	FIREWOOD	14.1113	0.4372	0.0284	[2]1.3841	38

[1]Significant beyond the 0.05 level.
[2]Significant beyond the 0.1 level.

the terrace (TRIBDEX); X_3 = rating of the beach area available for landing a boat (BOATLAND); X_4 = rating of the degree to which the campsite is protected from breezes (WINDPRO); X_5 = rating of the degree to which a campsite is screened from the river corridor (EX-SECLU) and accounts for 80 percent of the total variation. The analysis of variance for the above model indicated the F-ratio exceeded the F-distribution value at the 0.005 significance level. The model can, therefore, be rated a significant regression equation for explanation of the variation in PARTY-NIGHTS.

The best model for explaining the variation among PARTY-NIGHTS for noncommercial campers is:

$$Y + 7.4649 + 1.628\ X_1 + 0.9702\ X_2 + 0.9810\ X_3 + 1.225\ X_4 - 0.6185\ X_5$$

where: X_1 = the square feet of open area at each terrace (AREASIZE); X_2 = average channel size in square inches of the tributary providing potable water at the terrace (TRIBDEX); X_3 = percentage of campable area covered by shade between 2:00 p.m. and 6:00 p.m. (PM-SHADE); X_4 = rating of the beach area available for landing a boat (BOATLAND); X_5 = rating of the volume of dead, down, and driftwood available at the terrace or boat landing area (FIREWOO and accounts for 44 percent of the total variation. The analysis of variance for the above model indicated the F-ratio exceeded the F-distribution value at the 0.05 significance level. This model can also be considered a significant regressi equation for the explanation of the varia- tion in PARTY-NIGHTS.

DISCUSSION

Insight into the relation between camping and site characteristics is obtained by examining significant characteristics selected by regression analysis. Three site characteristics TRIBDEX, BOATLAND, and AREASIZE, were selected as significant predictor variables in both commercial and noncommercial camping models although not necessarily at the same step in the analysis (tables 5 and 6). The selection of these three characteristics means that the frequency of camping at a terrace is significantly correlated with the size of the tributary channel which supplies potable water to the site (TRIBDEX), the amount of area available to land a boat (BOATLAND), and

e size of the campsite area (AREASIZE). ch of these characteristics seems logi- l and important in the choice of a mpsite.

Although the analysis identifies a nctional relation between certain on- te characteristics of river terraces d the frequency with which they are osen as campsites, it must be noted at a cause-and-effect relation is not plied. Furthermore, there is an ab- nce of any data on the influence of the evious experience of the decision- ker(s) involved with campsite choice. ior experience camping in the river cor- dor (e.g., commercial guides) undoubtedly nditions choice behavior and this will, with other kinds of spatial search havior, "likely lead to a habitual set responses and a stable movement pat- rn" (Murphy and Rosenblood, 1974). The esence of a conditioned response pattern r commercial groups can be suggested by e striking difference in the actual num- r of locations chosen by them (26) in mparison to the actual number of loca- ons chosen by the noncommercial parties 5). The difference in predictability the models for commercial and non- mmercial groups may also be related to e potential influence of prior perience.

CONCLUSIONS

This pilot investigation sought to entify characteristics of camping rties, their campsite choice patterns, aracteristics of all campsites, and e relation between the number of times campsite is chosen and selected charac- ristics of the campsite. The models r commercial and noncommercial par- es were formulated upon the groups' tual choice of campsites in relation measured characteristics of camp- tes. If some campsites in the study ea were to change due to seasonal ooding, and if we then knew the mea- red values of site variables, X_1 rough X_5, then we could probably timate the amount of camping that ch location would receive. Thus, tential shifts in camping patterns ong the corridor could be studied.

While the findings are limited to e population camping along the Rogue River, the campsite choice models raise several questions worthy of future re- search. To what extent are selected site characteristics significant pre- dictors of campsite choice in other river corridors? Are current campsite assessment procedures suitable for application in a variety of river settings? Is prior experience of camping parties an important factor to models which describe campsite choice behavior? In the future, the opportunity to predict variation in camping patterns could provide manage- ment agencies with a valuable tool for examining the likelihood of congestion or environmental degradation occurring at particular locations along the river corridor.

In summary: (1) Analysis of camping parties revealed commercial parties tend to be larger (15-25 people) than noncommercial (less than 15 people). The two groups differed substantially in type of boat used and slightly in their length of stay within the study area. Commercial parties chose fewer campsites (26) than did noncommercial (45). Both groups tended to choose the same camp- sites most frequently. Campsite choice behavior for commercial parties shows clustering. Noncommercial parties were distributed along the entire river corridor.

(2) Selected site characteristics of river terraces were significantly related to the number of times the location was chosen. This relation was presented in the form of two models, one for commercial parties, the other for noncommercial parties.

(3) Five independent variables were significant predictor variables for the dependent variable PARTY-NIGHTS (number of parties spending one night) in both the commercial and noncommercial camping models. Eighty percent of the variance in PARTY-NIGHTS was accounted for in the commercial model.

(4) Of the 5 significant terms selected for each model, 3 were the same variable. These were size of the camp- site, size of the tributary providing potable water to the location, and the ease with which a boat could land at the river terrace.

As stated by Lime (1975a), research is badly needed to cope with the numerous problems caused by growing recreational use of backcountry rivers. If the procedures utilized in this pilot study are used on other river settings and if research into campsite choice behavior is expanded, resource management agencies could eventually have models for predicting the intensity and distribution of river camping.

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RELATIONS BETWEEN RIVER TRIP MOTIVES AND PERCEPTION OF CROWDING, MANAGEMENT PREFERENCE, AND EXPERIENCE SATISFACTION

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ABSTRACT.--River users in Dinosaur National Monument were sampled during the summer of 1975. Trip motives, in descending order of importance to users, were found to be: action/excitement, learning about nature, stress release/solitude, affiliation, autonomy/achievement, self-awareness, and status. User scores on the motive scales were related to user perceptions of river crowding, to opinions on appropriate maximum group size, to campsite development strategies, to river management techniques, and to user satisfaction. A number of correlations were statistically significant, though relations tended to be weak. Research implications are discussed.

Whitewater rivers provide a particularly itful area for study of the ecological social impacts of intensive recreational and management. Float trips on the en and Yampa Rivers in Dinosaur National ument have increased dramatically in ent years; from about 2,500 floaters in 7 to more than 14,000 in 1971. Use lings were imposed prior to the 1972 son, but river use still increased to e than 17,000 persons. The number of aters declined in the years following to the energy crisis, but participation now climbing back up. The National Park vice has felt a need to determine the rying capacity of the rivers for float-p use, to develop strategies to hold use hin capacity, to analyze the social and nomic ramifications of river running, to provide guidelines for future decins. The present study was formulated to lore the social-psychological inputs to h decisions.

THEORETICAL FRAMEWORK

In order to make any judgments about human resource, you must understand the ure of it. When recreational use is a agement objective, the outcomes of the tem to be sought should be the maximizan of the satisfactions of the users (Lucas and Stankey 1974). Such outcomes are the "product" of the recreation resource system (Brown 1975). The following will provide a brief overview of recreation behavior and how satisfaction with recreation experiences may be derived. We will subsequently examine how these social psychological variables relate to decisions on use limitations, particularly with respect to carrying capacity.

Recreation Experiences

The major output of recreation management should be to satisfy users. But what determines satisfaction? Each person enters the recreation engagement with certain expectations about the particular experience. When a person enters a recreation environment, the perceived reality of the situation is compared to the person's own expectations. To the extent that perceived reality matches the expectations of the individual, satisfactions may be derived. It is possible likewise that certain expectations may not be met. If these are very important, dissatisfactions may result. For example, if one seeks solitude, the presence of others may preclude that. If one seeks communion with nature, ubiquitous facilities made necessary by high use levels may make that difficult. Thus, satisfaction is dependent on an experiential reality rather than a

physical one.

A particular resource may be perceived differently by various groups. A certain type of individual may perceive the resource as providing one kind of experience, and this may serve as a primary inducement to engage in recreation on the site. Another type of person may perceive an entirely different experience, and may also be motivated to use the site, but with very different expectations. To the extent that the different expectations are all met on the site, we can look with pride on the diversity of satisfactions that a particular resource may provide. However, it is becoming increasingly apparent that certain kinds of experiences may not be compatible, and that unrestricted and haphazard recreation management can result in the exclusion of certain recreation experiences.

In a wildland situation, certain experiences such as solitude can be disrupted by the presence of others. If solitude is seen to be a valuable experience, then active steps must be taken to avoid losing it. This may imply the designation and management of areas specifically for that purpose. If all experiences are likewise represented, then we can provide a recreational resource system that truly meets the needs of the people. Assuming that there is not enough recreational land to adequately handle all experiences and that everyone will not be completely satisfied all of the time, some kind of allocation and limitation decision is necessary.

A major thesis of this research is that to the extent that managerial objectives are defined in the context of *recreation* experiences, more clearcut criteria for *use limitation*[1] decisions are made available to managers. The designation of areas as providing certain experiences already exists. The National Wilderness Preservation Sy em provides for the establishment of units that have certain experiences as primar objectives. (In a broader context, the national parks also represent managemen for specific values.)

The designation of a particular ex rience to manage for begins to selectiv y filter out potential pre-emptive resour developments and management actions. T manager can gain additional input for d l- sion-making from users whose experience expectations most closely reflect the v ues he is managing for. This is essentiall what Stankey (1972) has proposed with esp to wilderness. He maintains that wilde ess management should be geared to those pe ons whose attitudes are most in concert wit he specific institutionalized values of wi er- ness as represented by the Wilderness A . Such a strategy may be more difficult t define when the experience expectations individuals are the reference point, bu this is more a methodological issue tha philosophical one. What has prevented effective evolution of this approach in e past is the insistence that researchers come up with *a* carrying capacity.

Once the commitment is made to man for experiences, however, it is possibl o focus on the dimensions of the use limi io or allocation problem, and what paramet will successfully serve to indicate the maintenance of the desired experience. e range of possible management actions to handle use levels provides leeway for t manager to act. There may be a number strategies, such as zoning, site manage t, or user distribution, that can serve to provide and maintain a particular exper ce

Management For Experiences

The present study sought not only explore the role of experience expectat s, but also to integrate this orientation o decision situations that may be useful managers. We have, therefore, attempte o place this theoretical approach into th context of a management model proposed Brown (1975). Brown's model has its foundations in the work of many wildlan recreation researchers, especially thos who have studied wilderness carrying capacity (Brown and Schomaker 1973 , Godf y and Peckfelder 1972 , Frissell and Stan 1972 , Lime 1970 , Lime and Stankey 197

[1] *Although carrying capacity is a widely used term, all empirical and theoretical work on it shows that there is no such thing as* the *carrying capacity for a given recreation resource. Rather a range of managerial options that may relate to many different situations and circumstances exists. The phrase "use limitation" still does not encompass the full range of these issues, but it at least is less suggestive of a single neat figure, and will be used here wherever possible in that context.*

Lucas 1973 , Lucas and Stankey 1974 , Stankey 1971 , Stankey 1973 , Wagar 1964). The contribution that Brown makes is to identify the management decisions that must be made and to specify in detail the inputs and outputs of each decision.

The first and most important decision that must be made is to select management objectives. The second decision is to select the management tools and techniques to meet the objectives. Finally, existing management objectives and strategies must be periodically evaluated to see if they should be modified; and if so, how.

Socio-psychological inputs play a vital role in all three of the above decisions. When selecting management objectives, it is advantageous for the resource manager to know which of the possible resource outputs are preferred by whom. In the case of Dinosaur National Monument, the white water rivers could be managed to provide opportunities for solitude, challenge, escape, nature education, self-reliance, excitement, esthetic appreciation, or affiliation. The park manager needs input regarding the experience expectations of users when he attempts to establish management objectives. Research has shown that motives are not the same for every individual participating in a given outdoor recreation activity (Davis 1973 , Henry and Driver 1974 , Knopf 1972 , Knopf, Driver, and Bassett 1973 , Potter, Hendee, and Clark 1973). Therefore the first hypothesis of our study was: river users on the Green and Yampa Rivers in Dinosaur National Monument have many motives for taking a river trip.

The manager also needs socio-psychological input from users when he selects management strategies. People's preferences for or satisfactions with river management strategies help the park managers to determine if management objectives are being met. Satisfaction in any situation is dependent upon one's expectations with respect to that situation (Lawler 1973). Limited research on the preferences and satisfaction of recreationists tends to confirm this contention (Bassett *et al.* 1972). On this foundation, the following study hypotheses were derived: Users with different motives for taking river trips differ (1) in the number of people they prefer to see on the trip, (2) in their preferences for maximum group size, (3) in their preferences for river campsite management, and (4) in their preferences for river management policies.

Finally, the park manager needs input from users in his evaluation of management objectives and strategies. If river users in Dinosaur National Monument are *satisfied* with their experience, then managers have accurately defined a socio-psychological carrying capacity. If, however, users are dissatisfied, then managers need to know who is dissatisfied and why. Brown's conceptualization of carrying capacity suggests that providing a great variety of satisfying experiences on the same river at the same time is probably impossible because what would enhance one river experience might detract from another. Discrepancy theory, which states that satisfaction is determined by the difference between desired outcomes and perceived outcomes, supports Brown's contention. On the basis of these theoretical and conceptual considerations, the final study hypothesis to be tested was: users with different motives for taking river trips differ in their degree of satisfaction with the trip.

STUDY DESCRIPTION AND PROCEDURES

Dinosaur National Monument, located on the boundary of Colorado and Utah, includes about 46 miles of the Yampa River and 43 miles of the Green River. Auto access to the rivers is limited to just a few places. Virtually all overnight river trips begin at Deerlodge on the Yampa or Gates of Lodore on the Green. All float trips in Dinosaur end at Split Mountain. The Deerlodge to Split Mountain trip takes 3 or 4 days and the Gates of Lodore to Split Mountain trip takes 3 days. The National Park Service has established 11 campsites for the river users. These sites contain primitive toilets, picnic tables, and fire grates for cooking; camping is permitted in designated sites only.

Data for the study were collected at the Split Mountain take-out point during the months of May, June, July, and August in 1975. Sampled individuals were given a coded postpaid return envelope that contained a cover letter, a questionnaire, and a map of Dinosaur National Monument. The questionnaire was 4 pages long and took about 30 minutes to complete. At the same time, the research technician recorded the date, name, address, and code number of the sample subject. The response rate was 76 percent; 864 useable questionnaires were returned out of 1,150 actually distributed.

The study questionnaire was designed to obtain the following information from river users: (1) background characteristics, (2) trip motives, (3) description of trip, (4) opinions on river management and use, (5) attitudes toward wilderness areas, and (6) satisfaction with the river trip. A 38-item construct scale was developed to measure the nine trip motives believed to be important: solitude, stress release/ escape, autonomy/achievement, affiliation, self-awareness, action/excitement, status, learning, and experiencing nature. Sample subjects were asked to think back to their reasons for taking the river trip and to respond to scale items in that context.

RESULTS

Trip Motives

A factor analysis was done to see if the study's multidimensional motivation scale measured the nine different motives, and whether the items that were written to measure a given motive did load highly on one factor. Seven, rather than the hypothesized nine, factors were extracted. Factor 1 included both the learning and the experiencing nature items so was therefore called "learning about nature". The second factor extracted was named "stress release/ solitude" because it represented a combination of the hypothesized stress release/ escape and solitude items. The remaining five factors contained the motive item-clusters as anticipated. All seven factor scales except "status" had an alpha coefficient of reliability of 0.80 or higher; that of the status scale was 0.68.

Although a sizeable number of individuals rated each motive as at least somewhat important, the relative importance of the motives for the group as a whole differed considerably. The action/excitement and learning about nature motives were very important, stress release/solitude and affiliation motives were moderately important, and autonomy/achievement was a somewhat important motive for most river users. Self-awareness and status had low group means.

Preferences For River Use Density

About 60 percent of river users either had no opinion about the number of people seen on the trip or felt that the number they saw was about right. Of the remaining individuals more felt they saw too many than felt they saw too few. Approximate 33 percent of users had no opinion on wh would be an acceptable number of encount with other people on the river trip. Am those with opinions, most felt that to se 11 to 25 or 26 to 50 people on the trip would be acceptable (only slightly lower than the number of people usually seen or the trip).

Pearson product-moment correlations computed to test for significant relation between motives for taking a river trip a preferences for river use density. It wa anticipated that the stress release/solit and self-awareness motives would have sig nificant positive correlations with river trip crowding and negative correlation wi opinions on appropriate levels of encount Because the affiliation motive represents a desire to be with and to meet friends, was predicted that affiliation scores wou have the reverse correlations, i.e., significant negative associations with perceptions of crowding and positive correla tions with decisions on appropriate use levels.

All of the hypothesized relations we found to exist at the 0.05 level of stat tical significance. However, the actual strength of the correlations was weak; no single correlation exceeded 0.20.

Preferences For Maximum Group Size

A large majority of river users, 84 percent, favored some sort of limitation on maximum group size. River users who favored the limitation of group size were also asked what they thought would be an acceptable maximum group size. User pref erences clustered in and around the 21 to 30 person category. These opinions seem reflect the existing situation; most trip on the river fall within this general siz range.

The same motives, for the same theoretical reasons that were considered impo tant in explaining opinions on river use, were also believed to be relevant to the question of limiting group size. The obtained relations were again very low; no correlation exceeded 0.20. The relations between three of the motives and opinions on limiting group size were, however, sig nificant at the 0.05 level of probability As hypothesized, there was a tendency for

an increase in the stress release/solitude motive to be associated with a shift in opinion toward favoring a limit on group size. The status motive had the opposite association, i.e., there was a weak tendency for individuals who were high in status to be opposed to limitations in group size. The affiliation motive was the only one that had a significant correlation with opinions on what would be an acceptable maximum group size. As predicted, the association was in the positive direction.

Preferences For Campsite Management

More river users opposed than favored campsite development suggestions. However, they were even more opposed to returning the river campsites to a more primitive or natural condition than to the proposed development. These findings suggest that existing river campsites are generally satisfying user needs.

It was hypothesized that scores on the learning about nature, stress release/solitude, and autonomy/achievement scales would each have a significant *negative* correlation with degree to which campsite development is favored and a significant *positive* correlation with support for preservation strategies at campsites. The correlation between motive scale scores and scores on the campsite development and preservation indexes were all below 0.20, but they were all statistically significant in the direction hypothesized (0.01 level of probability).

Preferences For River Management Policies

More than four times as many people favored campsite assignment and trip scheduling as opposed them. The establishment of a seasonal use limit was favored by overnight river users at a 3:1 ratio. The strength of the preference for trip scheduling is particularly striking because this policy does not directly apply in Dinosaur.

Because campsite assignment and trip scheduling would have an impact upon the number of people encountered on the trip and upon freedom of choice while on the trip, it was hypothesized that scores on the stress release/solitude and self-awareness scales would have significant positive correlations and scores on the autonomy/achievement and affiliation scales would have negative correlations with these river management policies. Because the establishment of more river campsites and seasonal use limit would likely reduce the number of contacts with other parties but would not decrease freedom of choice while on the river, it was anticipated that an increase in the stress/solitude and self-awareness motives would be associated with a significant tendency to support the establishment of campsites and a seasonal use limit, but that the affiliation motive would have a negative correlation with these management policies.

When product-moment correlations were calculated to test for the hypothesized relations, all of the correlations between motive scores and preferences for the four river management strategies were found to be very weak. No single correlation coefficient was greater than 0.15. Many of the weak correlations were statistically significant as hypothesized, however (0.05 level of probability).

Degree of River Trip Satisfaction

Eighty-three percent of overnight users either said they were completely satisfied or thought the trip was one of the most thoroughly satisfying experiences of their lives. Another 15 percent were mostly satisfied. Only 4 people out of 666 were somewhat dissatisfied.

Even though river users as a group were satisfied with the river trip, it was hypothesized that relations between individual trip motives and degree of trip satisfaction would differ. Pearson product-moment correlations were computed to test for such differences. Although none of the obtained correlations had an r value greater than 0.21, the correlations between all study motives and degree of trip satisfaction were significant at the 0.05 level of probability. Moreover, all significant associations were in the same direction, i.e., the greater the strength of the motive, the greater the degree of trip satisfaction.

DISCUSSION AND CONCLUSIONS

Although this study provided much information on user preferences and satisfaction that is useful for decision-making, the generally weak correlations between trip motives and both management preferences and

degree of trip satisfaction lowers the apparent value of this particular approach to the assessment of the socio-psychological components of carrying capacity. If river users who seek different experiences on the trip differ only slightly in their preferences for seeing people on the river or at campsites, for limiting group size, for campsite development, for specific river use regulatory policies, and in degree of trip satisfaction, then measurement of trip motives has little practical value for the river manager.

The motive scales used in this study sought to measure the phychological needs of the individual that prompted him to take the river trip. The conceptualization of trip motives at the basic human need level may have contributed to the weak association between reasons for taking a river trip and opinions on river management strategies. For example, individuals with a high need for affiliation may have very different expectations on how this need might be satisfied on the river trip. For some it might be group singing around the campfire, for others it might be preparing a meal together, or a hike up a side canyon with a special friend. These individuals likely prefer very different river management policies. In future recreation behavior research, stronger relations and more meaningful information for decision-making might be gained if the specific experience expectations of the recreationists are measured. When many recreationists in the research population have no previous experience with the activity or the resource in question, as was the case with the river users in Dinosaur National Monument, separate analyses should be performed for the experienced and inexperienced users.

In the measurement of the trip motives of river users in Dinosaur National Monument, more individuals scored high on all or almost all motives or scored low on all or almost all motives than expected. This may be due to response sets among river users. A Likert-type attitude scale is susceptible to such response sets, and the finding that individuals who had strong trip motives a[illegible] had a high degree of trip satisfaction su[illegible]gests that this may have occurred. A mor[illegible] accurate assessment of the importance of the various reasons for taking a river tr[illegible] might have been attained had the river us[illegible] been asked to *rank* his trip motives.

Because of financial constraints, tr[illegible] motives were recorded *after* the trip. Th[illegible] approach has several weaknesses. Human behavior is prompted by psychological nee[illegible] or strains within the individual (Lawler 1973). When the psychological need is satisfied, other wants become dominant. The high rate of river trip satisfaction reported suggests that users may have a difficult time remembering their original reasons for taking the trip. River users in Dinosaur National Monument may have onl[illegible] general expectations of their trip due to lack of previous river experiences. Thei[illegible] motives would therefore be susceptible to change due to actual resource and social conditions encountered on the trip. The post-trip measure of motives may be not s[illegible] much a measure of inherent reasons for taking a river trip as it is a measure of the trip's capability of providing variou[illegible] kinds of experiences. In future river and other recreation behavior research, motive[illegible] should be measured prior to the trip.

Trip motives mattered little in determining satisfaction. Virtually every rive[illegible] user was extremely satisfied. This may be due to several factors. First, most river users in Dinosaur apparently do not have well defined expected outcomes. They have not taken a previous river trip, and the experience is therefore exploratory in nat[illegible]. Second, the trip offers much diversity. T[illegible] resource and social characteristics of the river trip provide a variety of experience opportunities; and trip scheduling, use co[illegible]ditions, and management regulations apparently still permit the individual to freel[illegible] choose the desired alternatives. Finally, contrary to the study's theoretical perspe[illegible]tive, the actual outcomes of certain facet[illegible] of the trip may so exceed expected outcome[illegible] that dissatisfaction with other aspects of the trip may be more than compensated for.

ATTITUDES OF SALMON RIVER USERS TOWARD MANAGEMENT OF WILD AND SCENIC RIVERS

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ABSTRACT.-- One hundred and seventy-six Salmon River float boaters responded to a questionnaire that solicited their attitudes toward wilderness river recreation experiences and management. Factors relating to health and physical fitness, adventure, awareness of nature, communion with nature, and wilderness preservation were viewed favorably by nearly all respondents. Intensive management practices such as developed campsites, gravel roads and trails, picnic tables, garbage cans, and allowing power boats were rejected by almost all respondents.

Wilderness users have been studied in any contexts. Stankey (1973) studied ser opinions about management and carrying apacity of four wilderness areas and reated their opinions to wilderness-purist ttitudes. His summary provided managers ith answers about prevailing opinions mong wilderness users. The present study ttempts to provide similar information or users of a wilderness river. We include somewhat broader range of variables reating to demographic data, type of wildrness use, and attitudes toward management ractices. We then attempt to describe how his information can be used to develop anagement strategies.

The major objective of this study was o provide specific data on user attitudes s a basis for suggesting management trategies for the Salmon River Wilderness rea. Responses to scaled items on user xperiences and management preferences were lso structured to provide insight into anagement programs for other wilderness ivers.

The second study objective was to define relations between behavioral and demographic characteristics of users, recreation experiences, and user attitudes concerning wilderness river management.

As Hendee *et al.* (1968) point out, wilderness management decisions cannot be made on a purely majority vote basis. But it is still important to know the majority opinion when evaluating management alternatives. Hendee *et al.* isolated a number of factors related to Pacific Northwest wilderness user attitudes. One purpose of the present study was to see if similar attitude dimensions would emerge from data collected from wilderness river users.

STUDY METHODS

Data Collection

Questionnaires were distributed during summer 1973 to a sample of Salmon River

users as they embarked on their float trips from campsites along the river. It was not possible to obtain a random sample of users because of unpredictable departure patterns. Instead, questionnaires were distributed at random times as people departed from campsites along a 75-mile stretch of river from Salmon Falls to the end of the road upriver from Riggins, Idaho.

When groups of 10 or more were departing together, only every 10th person was given a questionnaire. For smaller groups, a questionnaire was given to one randomly selected individual. Selected individuals were given a brief description of the study, handed a questionnaire, and asked to fill it out and return it at the completion of their trip. Of the 250 questionnaires distributed, 191 were returned. Of these, 176 were used in the analysis. Most of the unusable questionnaires had been damaged by water.

Although not complicated, the questionnaire was lengthy. We attribute the rather high rate of response to the users deep interest in management of the Salmon River.

The questionnaire was divided into four sections: (1) questions about the user, his group, mode of travel, length of visit, expenditures, and past and present activities on the Salmon River and other wilderness areas; (2) a series of questions to elicit attitudes about 47 features and activities associated with the Salmon River and the user's recreation experiences; (3) another series of questions to elicit attitudes on 50 items related to existing and alternative Salmon River management practices and facilities; and (4) demographic information on the respondent--age, residence, income, sex, marital status, and organizational affiliations.

Scale items on attitudes toward the wilderness environment were derived largely from Hendee *et al.* (1968). This was done so that we could determine how results of our study of Salmon River users compared to Hendee's studies of nonwilderness river users.

Data Analysis

Responses were coded and punched on cards for computer analysis, and data were analyzed as follows:

Descriptive analysis--Demographic and recreation behavior variables were tabula

Factor analysis of attitudinal data--The scaled items on recreation experiences an management practices were factor analyzed separately to define clusters of attitude and thus provide a simple overview of the data. Five factors were defined for item dealing with recreation experiences, and three factors were defined for items dealing with attitudes toward management practices. Only those attitudinal items with loadings of 0.40 or greater on any of the eight factors were retained for furth analysis. Scale directions of individual items with negative loadings were reverse to preserve the statistical and empirical meaning of each factor.

Attitude-behavior patterns--Factor scores were calculated for each respondent based on items loaded on the eight factors defi above. By this process, the 97 individua item scores were distilled into 8 factor scores. Each resulting score represented a dimension that best described the variation in responses to the individual items loaded on the factor describing that dimension.

The eight factor scores, demographic data, and recreational behavior data for each respondent were subjected to a final factor analysis. This analysis produced three attitude-behavior patterns that related attitude, demographic variables, and recreation behavior of Salmon River wilderness users.

RESULTS

Descriptive Results

Demographic and recreation behavior data were analyzed to produce a descriptio of the "typical" Salmon River user.

The "typical" Salmon River user was on his first trip to the Salmon, but he averaged almost two trips annually to other wilderness areas. He prefers to see few people in the wilderness. On this visit to the Salmon River, he went with a guided group, and spent less than $600 for the entire trip. He stayed for 5 nights each of which he slept outside at a satisfactory campsite. He found the Salmon

ver relatively unlittered and was very
tisfied with his trip. It is not surising that he camped at night and did ttle hiking, because all study respondents re floating down the Salmon River.

Attitudes Toward Recreation Experiences

Factor analysis of questionnaire items aling with aspects of recreation behavior d experiences resulted in the definition five factors (tables 1-5). To code data r factor analysis, responses for each estionnaire item were scored on a scale 1 to 9: very unfavorable responses were ored 1, neutral responses 5, and very vorable responses 9. Descriptive factor mes were determined by examing the individual items most heavily loaded on them. ctors should not be interpreted as presenting consensus among respondents. e to the nature of factor analysis, both spondents with characteristics or attitudes scribed by the factor and those with posite characteristics or attitudes are kely to be present in the sample.

Such variation in response is necessy if a definable factor is to emerge from e data. Item loadings on factors can be ewed as correlations of the item (variable) th the factor, i.e., the strength of the lation between a particular item and all her items comprising the factor.

The items loaded on "adventure and newal", recreation experience factor 1 able 1), were highly regarded by most spondents, having a mean rating across e factor of 7.8 out of a possible 9. The presence on this factor of items representing a desire to recapture the pioneer spirit, experience a sense of discovery, seek adventure, and get physically tired indicates that people favoring items on this factor would oppose any management practice that would "tame" the wilderness.

ble 1.--*Adventure and renewal (recreation experience factor 1)*

Item	Mean item rating	Factor loading
ttitude toward:		
ttain new perspectives	7.7	0.82
mprove health	7.7	.81
ecapture pioneer spirit	7.1	.77
xperience sense of discovery	8.0	.72
elieve tensions	8.0	.68
o things most people don't	7.2	.68
xperience sense of adventure	8.0	.65
et physically tired	7.6	.63
reath fresh air	8.7	.46
xperience self realization	7.8	.45
Factor mean	7.8	

"Convenience", recreation experience factor 2 (table 2), provides a cluster of items relating to more convenience-oriented recreation facilities. People with favorable attitudes toward these items prefer to have all the comforts of home when they engage in wilderness recreation. It should be noted that preference for sleeping outdoors is negatively related to the factor indicating that those who like car camping, developed resorts, etc., would prefer not to sleep outdoors.

Table 2.--*Convenience (recreation experience factor 2)*

Item	Mean item rating	Factor loading
Attitude toward:		
Car camping	2.4	0.77
Developed resorts	2.2	.75
Purchasing souvenirs	1.8	.72
Automobile touring	2.4	.71
Power boating	2.6	.70
Private cabins	3.1	.70
Campsites with plumbing	2.9	.68
Gravel roads	3.3	.60
Sleeping outdoors	8.5	- .43
Factor mean	2.4	

The low mean rating for recreation experience items on this factor (2.4 where 1 is the lowest possible and 5 is neutral) indicates that most Salmon River users reject easy types of recreation. This finding is consistent with results of most other studies of wilderness users. People favoring recreation experiences described by the factor would probably be infrequent wilderness users.

The mean rating of items loaded on "strenuous activity", recreation experience factor 3 (table 3), is 8.0. This indicates that strenuous physical activities are highly regarded by most Salmon River users. Nevertheless it should be remembered that most of the recreationists sampled did little hiking. Perhaps what is sought is the opportunity to do such things, rather than actually doing them.

Table 3.--*Strenuous activity (recreation experience factor 3)*

Items	Mean item rating	Factor loading
Attitude toward:		
Hiking	8.4	0.65
Mountain climbing	7.5	.63
Backpack camping	8.1	.60
Physical exercise	8.2	.54
Factor mean	8.0	

Recreation experience factor 4, "aesthetic pleasure", (table 4), consists of items related to aesthetic enjoyment of elements in the natural environment. All items had high ratings from most respondents, resulting in a higher mean rating (8.5) than that of any other recreation experience factor. This dimension of appreciation of nature and aesthetic enjoyment is important to most Salmon River users.

Table 4.--*Esthetic pleasure (recreation experience factor 4)*

Items	Mean item rating	Factor loadings
Attitude toward:		
Vast areas	8.2	0.72
Timberline vegetation	8.2	.72
Virgin forest	8.4	.71
Rugged topography	8.2	.68
Seeing native wild animals	8.7	.67
Looking at scenery	8.7	.63
Float boating, kayaking	8.5	.62
Awareness of beauty	8.8	.58
Enormous vistas	8.1	.58
Absence of people	8.2	.56
Enjoyment of nature	8.8	.55
Drinking clean stream water	8.8	.55
Solitude	8.5	.53
Tranquility	8.7	.52
Absence of man-made features	8.3	.50
Absence of man-made noise	8.5	.41
Factor mean	8.5	

Recreation experience factor 5, "hunting and fishing" (table 5), deals specifically with attitudes toward hunting and fishing in the wilderness. Whereas not all hunters are fishermen and vice versa, attitudes toward these activities are closely related. But fishing is viewed as generally more appropriate. Hunting has the highest standard deviation (3.05) of any of the recreation experience items included in the study. This indicates a great diversity of opinion with regard t[o] its appropriateness.

Table 5.--*Hunting and fishing (recreati[on] experience factor 5)*

Items	Mean item rating	Factor loading[s]
Attitude toward:		
Hunting	4.4	0.74
Fishing	6.6	.66
Factor mean	5.4	

Attitudes Toward Management Alternatives

Factor analysis of items about wilderness management and behavior resulted i[n] the definition of three factors (tables 6-8). Individual items were scored on a scale of 1 to 3: where undesirable-disagree responses were scored 1, neutral responses 2, and desirable-agree as 3.

The items on management factor 1, "development" (table 6), indicate a dimension of concern for the degree of development appropriate for a river wilderness area. People who reacted positively to these items (and negatively to negatively loaded items) likely perceived the wilderness as idle land that should have more intense use. The introduction of some degree of managed, mechanized civilizatio[n] would be appropriate to these people. Most Salmon River users in our sample wer[e] at the other end of the spectrum as indic[ated]

Table 6.--*Development (attitude toward management factor 1)*

Items	Mean item rating	Factor loadin[g]
Attitude toward:		
Power boats in wilderness	1.2	0.69
Helicopters for VIPs	1.3	.64
Leasing land to guides	1.3	.62
Airfields in wilderness	1.5	.61
Continued use of powerboats	1.6	.54
Packing out garbage	2.7	-.53
Leaving garbage in cans	1.4	.50
Motor noise in the wilderness	1.3	.51
Picnic tables at campsites	1.3	.49
Grazing of livestock in backcountry	1.5	.49
Private land inholdings	1.4	.47
Cutting vegetation for bedding and fire	1.4	.44
Removing signs of use	2.8	-.38
Factor mean	1.4	

by the low individual item means and the low overall mean of 1.4. They prefer to see the wilderness undeveloped. As shown by the loadings of the two items concerning power boats and items about helicopters, airfields, and motor noise, they disapprove of noise associated with mechanization. The types of development described by this factor would be unpopular with most Salmon River users.

The items on management factor 2, "secure wilderness" (table 7), all have mean ratings near neutral, producing an overall factor mean of 2.1. These neutral means were produced by great diversity of opinion as indicated by high item standard deviations. All strongly loaded items concern use of signs and helicopters in the wilderness. People who favored these items might desire signs so that they do not get lost, and desire helicopters in case they do. This group of respondents might feel insecure in the wilderness, probably being infrequent wilderness visitors. More experienced wilderness users probably express the opposite attitude. The manager contemplating use of signs or helicopters in wilderness river areas should understand that opinion on the issue is diverse. Infrequent users are likely to approve of these management techniques while frequent users might be opposed.

Table 7.--*Secure wilderness (attitude toward management factor 2)*

Items	Mean item rating	Factor loading
Attitude toward:		
Campsite signing	1.9	.70
Interpretive signing	2.1	.70
Signing of dangerous rapids	2.2	.66
Signs on streams	2.1	.64
Removing existing signs	1.7	- .63
Helicopters for patrols	2.0	.49
Helicopters for administration	1.9	.47
Helicopters for carrying equipment	1.9	.42
Factor mean	2.1	

Six well-regarded items make up management factor 3 (table 8), "controlled access". People responding positively to these items like to see trails minimized in both number and quality. They also favor restrictions on use and like to see wilderness areas managed as separate from surrounding land units. This factor relates to the amount of use deemed appropriate within wilderness areas. Restrictions on levels of use should be favored by most Salmon River users. A similarly favorable attitude toward restrictions on use has been found with other groups of wilderness users (Stankey 1973).

Table 8.--*Controlled access (attitude toward management factor 3)*

Items	Mean item rating	Factor loading
Attitude toward:		
Leaving fallen trees across trails	2.3	.69
Low standard trails	2.5	.61
Limiting group size to 12	2.3	.60
No trails in some areas	2.7	.51
Managing wilderness differently from adjacent lands	2.8	.46
Restrictions on number of users	2.9	.41
Factor mean	2.6	

Attitude-Behavior Patterns

Scores were calculated for individual respondents on each of the eight factors previously defined. These scores were then subjected to another factor analysis along with variables on respondent demographic characteristics and recreation behavior. The analysis resulted in the definition of 3 factors that we call "attitude-behavior patterns" (tables 9-11).

Respondents expressing the attitudes and having the characteristics reflected in attitude-behavior pattern I, "purist-preservationist" (table 9), tend to reject any type of increased development of the

Table 9.--*Purist-preservationist (attitude-behavior pattern I)*

Variable or factor	Pattern loading
Convenience (recreation experience factor 2)	- 0.64
Secure wilderness (attitude toward management factor 2)	- .51
Development (attitude toward management factor 1)	- .50
Controlled access (attitude toward management factor 3)	.48
Preservationist group membership	.48
Number of wilderness trips per year	.43
Number of people tolerated in wilderness	- .39
Years of schooling completed	.32
Amount of littering perceived in Salmon area	.31
Strenuous activity (recreation experience factor 3)	.29
Aesthetic pleasure (recreation experience factor 4)	.28

Salmon River area--particularly developed camping facilities. An individual displaying this pattern would likely be well educated, a frequent wilderness user, and a member of a preservationist organization. Such a person would prefer seeing few other people in the area and view the Salmon River area as being in worse condition with regard to littering than others. They may, in fact, be more discriminating in their perception of wilderness.

People represented by the "purist-preservationist" pattern prefer controlled access and physically rugged forms of recreation. They enjoy the outdoors, reject convenience-oriented camping, and oppose intensive management and development. They are more experienced wilderness users than other Salmon River users, and are intolerant of crowded conditions. People represented by the "purist-preservationist" are more likely to be preservationist group members than are other Salmon River visitors. They prefer management to keep large numbers of people out of the Salmon River area and to preserve the wild character of the area. It is important to note that these more frequent users are most opposed to development.

People described by attitude-behavior pattern II, "hunter-fisherman" (table 10) tend to camp alone, not hire a guide, react more favorably toward convenience facilities and approve of hunting and fishing in the wilderness. They are frequent visitors to the Salmon River, probably coming to hunt or fish. They like to see few other people in the area, which is consistent with the needs of hunters and fishermen. People who display opposite characteristics are likely to be members of a guided tour group on their first visit to the Salmon River.

Table 10.--*Hunter-fisherman (attitude-behavior pattern II)*

Variable or factor	Pattern loading
Hiring of a guide	- 0.56
Number of people in group	- .53
Camping with group	- .50
Number of times been at Salmon	.45
Hunting and fishing (recreation experience factor 5)	.38
Development (attitude toward management factor 1)	.35
Number of people tolerable in wilderness	- .32
Secure wilderness (attitude toward management factor 2)	.28

Attitude-behavior pattern III, "wilderness enthusiast" (table 11), represent young, single people who are new to the Salmon River and are looking for a challenging, rewarding experience with nature. Respondents having opposite characteristi would be older people with families who could do without the challenge. The youn adventurous user would be more common on the Salmon River.

Table 11.--*Wilderness enthusiast (attitud behavior pattern III)*

Variable or factor	Patter loadin
Adventure and renewal (recreation experience factor 1)	0.65
Aesthetic pleasure (recreation experience factor 4)	.64
Strenuous activity (recreation experience factor 3)	.49
Age	- .48
Number of children	- .41
Married	- .36
Number of times at Salmon	- .32
Controlled access (attitude toward management factor 3)	.27

DISCUSSION

Study results, when compared to resul of other wilderness user studies, provide insight into differences and similarities between wilderness user groups that can be used to develop management strategies.

Relation to Results of Other Studies

Results of this study were similar to results of other studies of wilderness use The factor analysis on attitudes toward th river wilderness experience showed strong similarity to results obtained by Hendee *et al.* (1968). This suggests that wilderness user attitudes are relatively stabl across different kinds of wilderness experiences.

Although attitudes toward the wilderness experience itself were similar, differences were found in attitudes of Salmon River users toward management alternatives Salmon River users, for example, are likel to have less wilderness experience than other wilderness users. Although Hendee *et al.* found that their sample of wildernes users averaged 6.3 wilderness trips per year, our sample of river users averaged only 1.7 trips per year to wilderness areas.

The finding of the present study that ilderness users would respond favorably oward a management program to restrict se was similar to that found by Stankey 1973). The ambivalent attitude toward he use of signs and helicopters, however, as not expected. Stankey (1973) found hat about a third of the users of four ilderness areas would approve signing ampsites. About the same percentage xpressed approval of such action in our tudy, but only another third actually pposed such an action. The implication is hat there is no universal opinion among almon River users as to the appropriateness f campsite signs. Whichever decision the anager made, an equal number of users would e unhappy.

Management Implications

It is important for the manager to nderstand the attitudes of the users of he area he is managing: not only the degree f similarity in user attitudes, but more mportantly, issues on which user attitudes re most divergent.

If the manager directs his management oward those who are of the "purist-preservationist" orientation, interests of n "elite" recreationist group would have been served to the exclusion of a large segment of the public who support wilderness through taxes. The gradations of management intensity associated with different categories of wilderness do not really resolve the issue. The question still remains about the appropriateness of functional exclusion of large segments of the public.

It may be that there is no "right" answer for the manager. Perhaps there are only those that are less wrong. If so, the major guidance for management should come from those who actually use the wilderness. Frequent Salmon River users who were sampled in this study prefer imposing restrictions on number of users, keeping trails few in number and low in quality, minimizing interpretive and directional signs, and forbidding the use of helicopters in the wilderness river.

The problems faced by the wild and scenic river manager are not much different than those faced by managers of other wilderness areas. Both deal with users who have a purist-preservationist attitude toward wilderness management. But the wild and scenic river manager is more likely to face problems associated with use by large groups of users who are inexperienced with wilderness and desire a measure of security.

A FILTER SYSTEM FOR DETERMINING RIVER SUITABILITY FOR NATIONAL WILD AND SCENIC RIVER STATUS

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ABSTRACT.--A system of filter matrices has been devised and applied to rivers in the Appalachian plateau. Based upon subsequent aerial observation and input from users, the system appears to be successful in identifying streams that could logically be considered for inclusion in the National Wild and Scenic River System.

I was part of a study commissioned by the Bureau of Outdoor Recreation (1976) to examine the Appalachian Plateau (exclusive of the Cumberland Plateau Region) to identify those streams which were suitable for study for inclusion in the National Wild and Scenic River System (fig. 1). In conducting this survey we experienced the three problems inherent in any selection process:

(1) Criteria;
(2) Consistency in application of criteria; and
(3) The comparison of dissimilar types--in this case rivers resulting from widely different geological and hydrological characteristics.

We found that many of the early systems used for categorizing rivers which used weighting values to determine river suitability for protection, had an inherent bias in that they favored the extremely long, big, high gradient rivers of the western mountains. In the East, due to the headstart in settlement, development has largely precluded the availability of hundreds of miles of free flowing streams or of rivers with large volumes of flow in pristine condition. This realization in turn caused a little waffling among agencies about the rigidity with which certain criteria should be applied. For instance, rivers are supposed to be 25 miles long or longer in order to qualify for Wild and Scenic River status. Because it is more difficult to find 25-mile to 50-mile continuous reaches of undisturbed streams in the East, the criteria have been softened to allow discontinuous reaches totaling 25 miles. Similarly, in the past any evidence of human intrusion such as dams, parallel

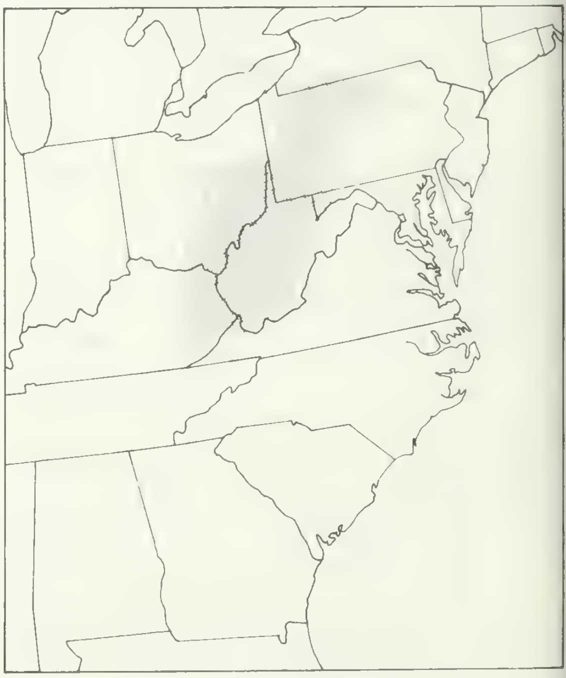

Figure 1.--*Study area.*

roads, or channelization has been enough to exclude a river. Now several rivers that are under consideration have dams in some segments with the Wild and Scenic portions beginning at the base of the dam and continuing through essentially untouched reaches.

Being aware of the relaxation of these criteria and the biases associated with different sections of the country, we felt that there was little use in studying all streams to see if 25 miles could be assembled from pieces of them. We also attempted to incorporate the perceptions of local citizens who, because of their familiarity with the various streams, knew their limitations and potentials. If, in fact, public input was strongly in favor of the consideration of a stream in spite of the fact that it did not meet all the criteria for National Wild and Scenic River status, it was included with appropriate notation.

SELECTION PROCESS

The technique we employed for comparing the various stream segments was a series of "filters" and "filter matrices" through which the streams were screened. A filter matrix is basically a cross check of items against values (e.g., apples and oranges against Vitamin C content, keeping doctors away, etc.). The values may be expressed in levels, giving qualitative or--in some cases--quantitative differences. If an item (e.g., a river) meets the proper criterion level, it is passed on to the next filter. If it does not pass, it is dropped from further study. The various filters are arranged in such an order that the first filters remove the most items from study, with each progressive filter increasing the standards. This allows items that obviously will not meet the standards to fall out early, reducing the number of items requiring detailed study. While there is a degree of subjectivity inherent in the personal observation portion of this technique, the filters and matrices themselves provide a framework of objectivity.

PUBLIC INPUT

User input was solicited from approximately 150 organizations. The groups covered all special interests from Audubon Societies and Sierra Clubs to Ducks Unlimited and Trout Unlimited as well as river-running canoe clubs, commercial rafters and any other groups who surfaced and had a real interest and knowledge of the streams. Our response rate was only 10 to 15 percent but many of these users were extremely specific and detailed in suggesting streams. We attempted to temper the hard and fast criteria applied in the filters with the information and desires we obtained from the dialogue with the various user groups.

Filter One--Stream Length

The initial filter we established was length. Under this filter all rivers and streams of 25 miles or more in length were identified. The U.S. Geological Survey (USGS) shaded relief and topographic maps (1:250,000) were found to be the best for this task. A stream which appeared on these maps was assumed to be of sufficient size to have recreation potential. This eliminated many of the small, first order streams and undoubtedly dropped some scenic small streams. Exceptions were made under this filter. We found that user input does not generally discriminate by length, therefore, some short segments were considered. Also, some of the recreationally important streams which did not conform to Filter One criteria but possessed unique characteristics which merited further consideration were passed on for further study.

Filter Two--Water Quality

The streams which passed Filter One were sequentially surveyed for water quality (figs. 2-6). The criteria required the stream or stream segment to meet or be capable of meeting within the next ten years, the water quality standards for water contact recreation. Several problems were encountered under this filter. There was a surprising variance among States' water quality standards and some States did not have separate standards set for categories of recreation, drinking, fishing, etc. For a number of stream segments, especially in West Virginia and Ohio, there was no data available. Where this occurred the streams were passed through to the next filter. The really hard item to get a handle on was the future water quality of each stream. In many cases it could not be determined whether or not the stream could meet the criteria within the 10-year time frame. Still, this filter was applied

stringently where the data was available. Any rivers identified by user input as valuable and recovering from water pollution were inserted into the analysis process. The water quality filter included the following parameters: (1) coliform bacteria (fecal), (2) dissolved oxygen, (3) pH (level of acidity), (4) toxic chemical, (5) heavy metals, and (6) β - particles.

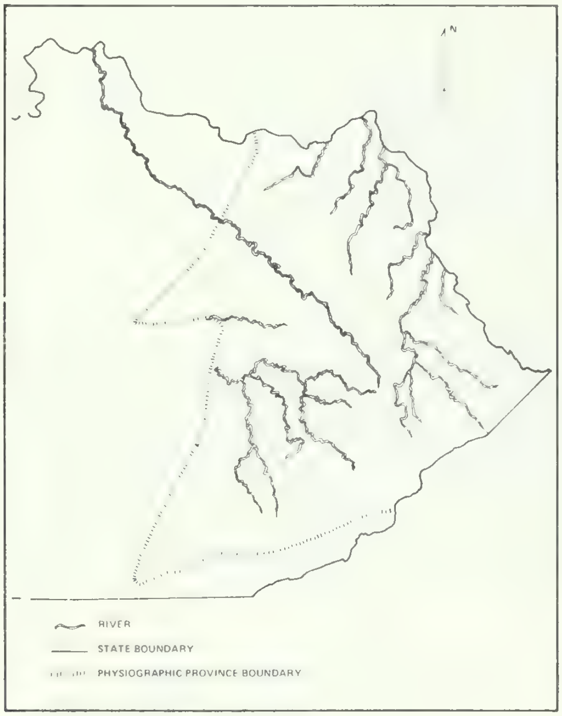

Figure 2.--*Location of surveyed rivers--eastern Kentucky.*

In restrospect the only water quality parameter which should have led to exclusion was frequent occurrence of high numbers of fecal coliforms during low-flow conditions. Such fecal coliform low-flow pollution may pose an actual health threat, whereas acidity, phenolic content, and heavy metals from infrequent, casual contact do not, though they may preclude wildlife.

This filter removed only 47 of the 150 streams passing Filter One because of the incomplete or widely varying water quality data.

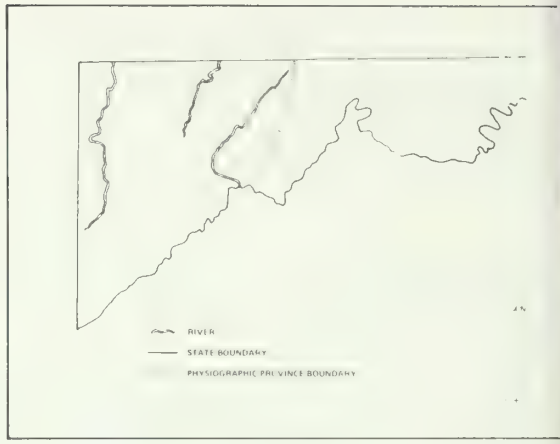

Figure 3.--*Location of surveyed rivers--western Maryland.*

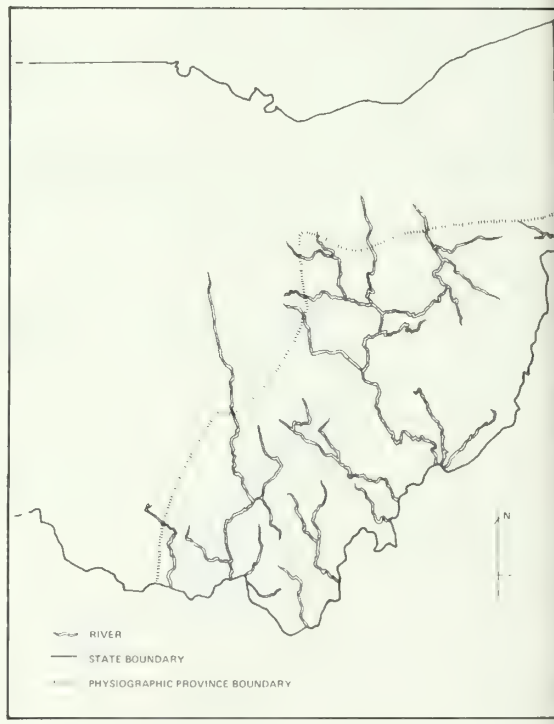

Figure 4.--*Location of surveyed rivers--Ohio.*

Filter Three--Urbanization

While many streams "fell out" due to water quality, the greatest impacts on streams are man-made intrusions and alterations. This most important filter was

produced in an effort to detail and quantify the degree of urban and agricultural development for each stream and to rank each river on an "urbanized" scale. We simply mapped a 0.5-mile river corridor on a suitable map and counted all noticeable cultural intrusions by down-river mile. This allowed for a mile-by-mile inventory of linear and nonlinear intrusions.

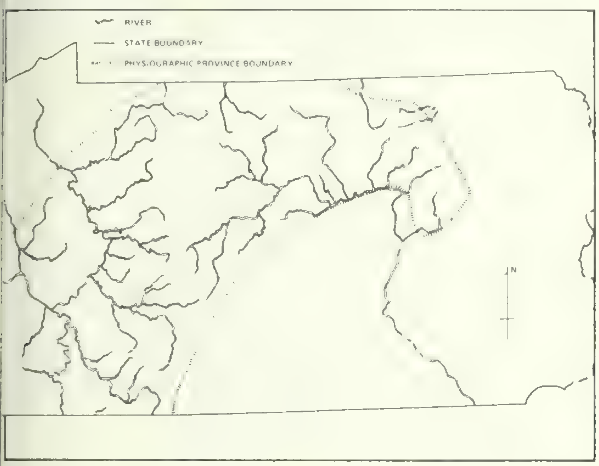

Figure 5.--*Location of surveyed rivers--Pennsylvania.*

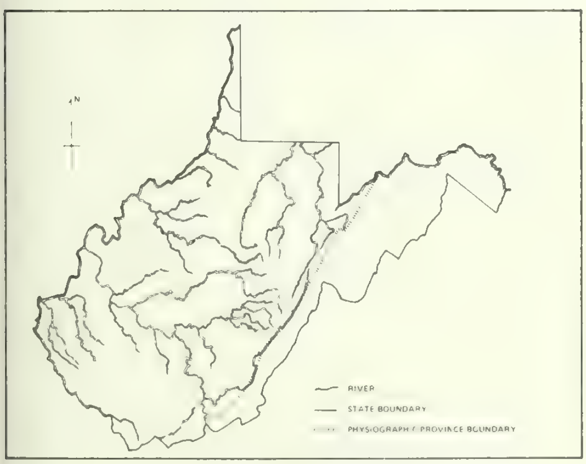

Figure 6.--*Location of surveyed rivers--West Virginia.*

Each intrusion was recorded by mile number and assigned a value on a scale from 1 to 100 by increasing human activity and visual intrusiveness, as tabulated below.

Weighted Value	*Intrusions (Linear and Nonlinear)*
1	Trail ending
2	Trail parallel, gauging station, water well
3	Road (dirt) ending, railroad grade crossing, ford
4	Road (dirt) bridge, gate
5	Road (dirt) parallel, road (gravel) ending, railroad ending, road (paved and rail), culvert, crossing, railroad grade parallel, orchard, ranger station, foot bridge, wayside park, country club, swimming pool, bathing area, cabin, dwelling
6	Road (gravel) bridge
7	Road (gravel) parallel, road (paved) ending
8	Road (paved) bridge, railroad bridge, covered bridge, pipe and power line crossing
10	Road (paved) parallel, railroad parallel, storage tank, cemetery, dock, levee, power and pipeline parallel, Forestry Headquarters
15	Campground, business, railroad station, post office, apartment building, radio tower, multibuilding camp, fish hatchery
20	School, church, armory, community hall, power substation, race track, recreation area, camping lodge, hospital, nursing home
25	Railroad yard, road construction
30	Mine, gas and oil well, sand and gravel pit, quarry, highway garage, correctional institute
35	Pumping station
40	Road (4-lane) bridge, resort, motel, drive-in, sewage plant, saw mill, trailer park
50	Factory, airport (small), 4-lane interchange
75	Road (4-lane) parallel, incorporated area, industrial section, auto dump, oil field (more than 3 wells), garbage dump
100	City, dam, canal

These values resulted from the synthesis of the perceptions of professionals familiar with river recreation, planning, and visual design. For example, trail

endings received a value of 1, intrusions such as a dirt road had a value of 3, a railroad crossing had a value of 8, etc., until we reached the top of the scale where a city on one bank would carry a value of 100. With this ranking system each river segment surveyed was weighed mile by mile and then compared against a baseline river, the Chattooga River in Georgia. This river was selected because it is familiar to the study personnel and it is generally recognized as an ideal eastern Wild & Scenic River. One section of the Chattooga that had been classified as Scenic had an average point value of 23 points per mile. On the other hand, Section IV of the Chattooga which had been classified as a Wild River averaged only 5 points per mile. Using these 2 figures as a baseline, final standard values of 0-10 points/mile (Wild) and 11-30 points/mile (Scenic) were established. Those rivers or river segments exceeding 30 points per mile were considered to be too highly developed for Wild and Scenic status and were dropped at this point. However, here again, an option was left open to reinstate rejected segments if citizen input warranted reconsideration. It should also be pointed out that many of these streams could be of excellent recreational value despite the corridor development. A value breakout for recreational rivers was not made because of the great variability in recreation activities.

It is obvious that the relative ranking system, the various categories, and the classification standards for Wild and Scenic Rivers is arbitrary. However, the intrusions were systematically recorded on a per-mile basis, thus allowing anyone to attach his own weighting system to the data if desired. It also allows streams to be compared on some consistent basis from area to area and stream to stream.

This filter removed the majority of the streams under consideration at this phase and had been accomplished primarily from map interpretation. In order to make sure that this paper survey gave a fairly accurate picture of the urbanization of the corridors and that no drastic human development had accrued since the updating of the maps, Filter Four was employed.

Filter Four--Direct Inspection

This filter consisted of field examination of the remaining rivers either from the air or on the water. During these surveys checklists and photos were used to record and document observations. From this analysis detailed descriptions of streams and land use characteristics, physiographic resources, and unique resources were also developed. On the positive side "field truthing" also prevents the unnecessary exclusion of streams where recovery has already begun or development is along a ridgetop or in some other fashion hidden from the river traveler's view. An example of this is the New River where railroad yards, small towns, and various industrial developments occur on top of the New River Gorge within less than 0.5 mile of the stream but out of sight and without intruding on the user's perception.

The information from all four filters plus user input was used to draw up a tentative final list-of-stream segments for Wild and Scenic River recommendation (figs. 7-11). Before final clearance, however, application of one last filter was attempted.

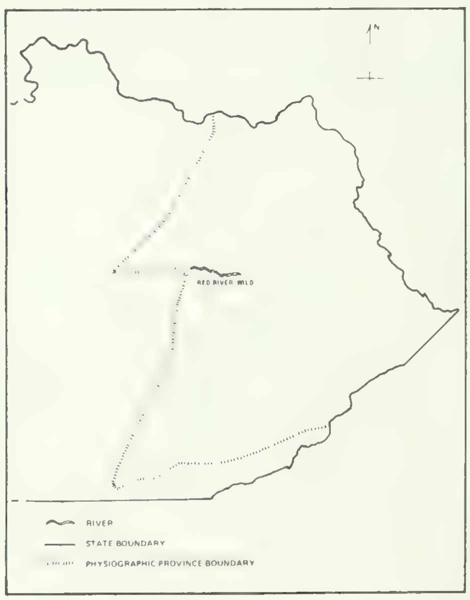

Figure 7.--*Rivers recommended for further study--eastern Kentucky.*

Filter Five--Water Flow

This filter included one of the six criteria for National Wild and Scenic Rivers: that a stream have sufficient volume of water during normal years to provide water-based recreation during a significant portion of the prime recreation

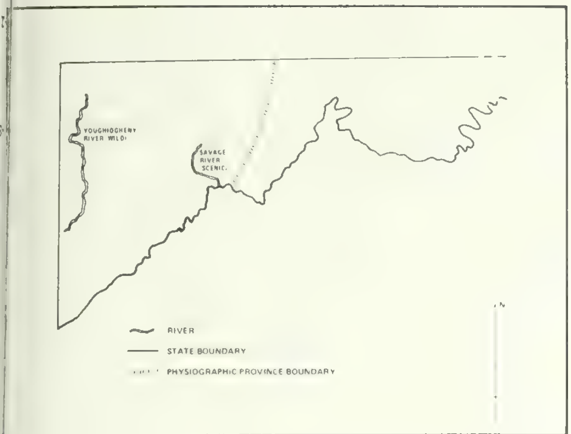

Figure 8.--*Rivers recommended for further study--western Maryland.*

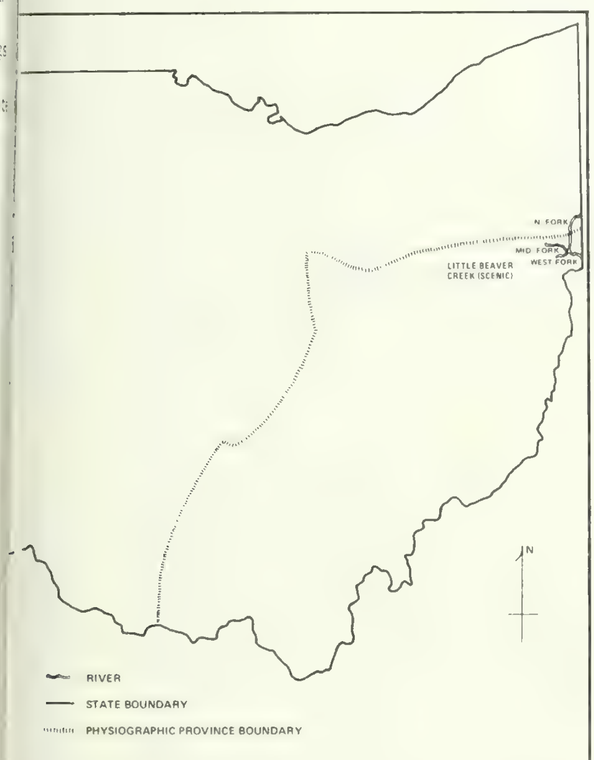

Figure 9.--*Rivers recommended for further study--Ohio.*

season. This dictates that stream hydrology be evaluated to determine use time. Data were collected from several sources and records on water resources were searched. Unfortunately, the data available were too scarce to adequately compare the streams surviving the other filters. As a result, the objective for this task was changed and instead of use as a filter, this data was used mainly for illustrative and informational purposes.

This may indeed be enough to determine stream suitability for potential study since recreation periods can be shifted to coincide with optimum flows. A good example of this is the Deep South Coastal Plains rivers which are nearly dry during the summer months, but provide ample recreation potential during spring, fall, and winter. These (what might normally be called off-season periods) in fact offer enjoyable recreational times in terms of climate, insects, and reptile contact. In other words, the nonsummer months when northern streams are generally not useable could be considered the prime recreation period for Deep South streams. Until certain terms such as "sufficient flow", "significant portion", and "prime recreation season" are defined, any filter developed using flow will remain weak and questionable.

STUDY CONCLUSIONS

We were not asked by the Bureau of Outdoor Recreation to rank the streams left after all the filters were applied, but one river did stand out as dictating examination for National Wild and Scenic River status. That river is the Gauley in West Virginia and it deserves mentioning at this point for a number of reasons. First of all, the Gauley may never be considered for Wild and Scenic River status because of political reasons. The Youghiogheny River in Pennsylvania, the New River in West Virginia, and several other lesser known rivers in roughly the same area are all being examined currently for Wild and Scenic River status. As a result of this clustering of qualified rivers, the political process may balk at declaring so many rivers in one area as Wild and Scenic and leave the Gauley unstudied.

Another reason for mentioning the Gauley is that although it stood out clearly as being desirable for study for Wild and Scenic status, it is not pristine in terms of the concept of western rivers. A dam sits at the head of the Gauley and a railroad track runs down the valley floor.

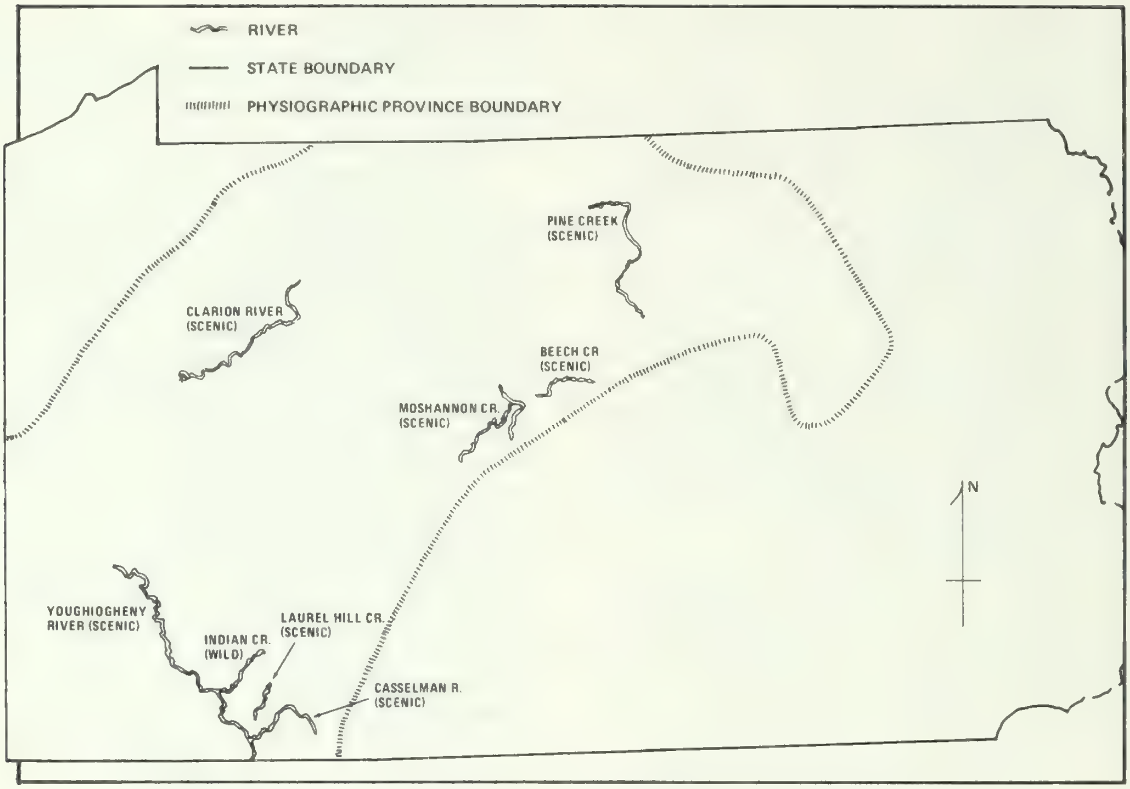

Figure 10.--*Rivers recommended for further study--Pennsylvania.*

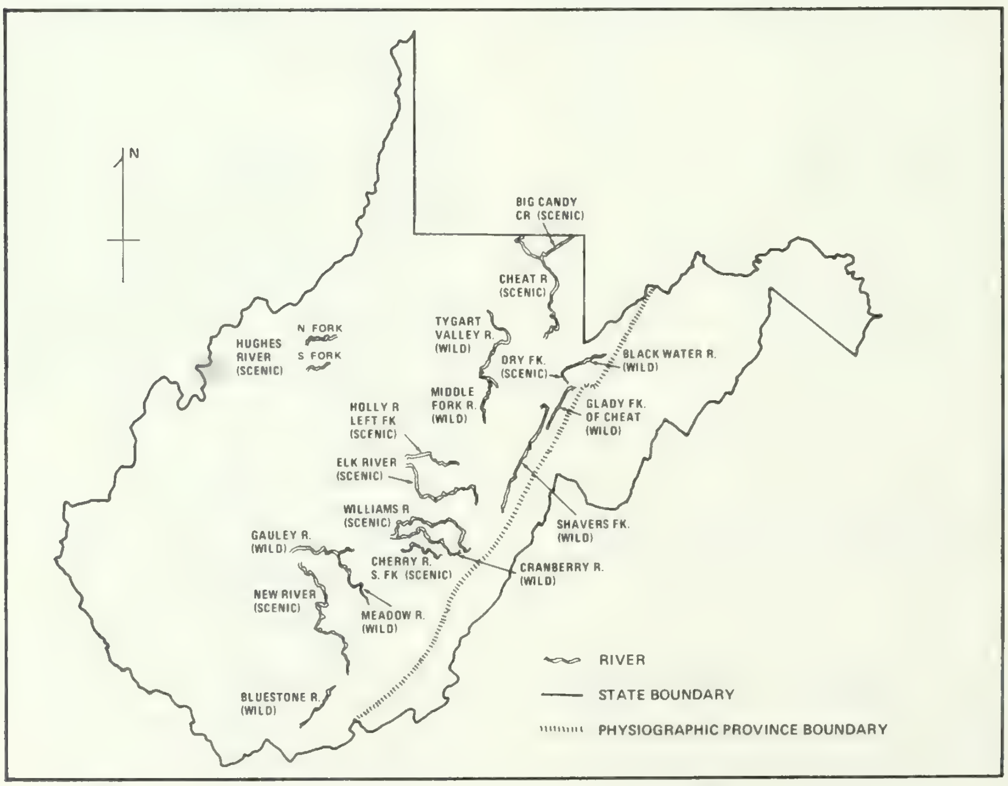

Figure 11.--*Rivers recommended for further study--West Virginia.*

wever, the railroad is out of sight of ie river traveler and is rarely used iile the river gorge is magnificent with gh walls and quality vegetation. Even ie Summerville Dam can be used as an asset actually enhance recreation use by cre- ting large volume flows (comparable with estern rivers) during periods of low ows in other streams. What this demon- rates is that first looks can be deceiving id an open, flexible evaluation system ist be maintained. Rivers are like people, iey have their own personalities and at- ributes that are not always easily dis- ernible. This does not mean that justifi- ation of any and every river can occur, it rather that a cookbook approach to such selection process must be tempered with ommon sense, evaluation of various poten- ials, and user perceptions.

One measure of importance that we did ot formulate, but that should be consid- red in future procedures and refined anal- sis of rivers already studied, is esthetics, ncluding auditory and olfactory stimuli. he sensations that the river corridor licits and the quality of these sensations re all important in the final analysis. uch an undertaking would have to be con- ucted in the final analysis of the evalua- ion periods because it requires on-stream nterpretation.

An esthetics survey can be facilitated by analyzing segment by segment the stimuli and moods evinced by the river setting. Subjectivity could be largely removed from this analysis by utilizing several observers all of different psychological bent and aggregating their results. That river providing the greatest variety of stimulating environmental settings and thus soliciting the widest variety of travelers' moods would have the greater esthetic appeal. Such an undertaking might again temper the original bias which exists for large, fast flowing rivers.

In summary, the results of the study (table 1) showed that the most important, hard (quantitative), criterion by which to evaluate rivers for Wild and Scenic status is degree of development or urbanization. Simple and inexpensive to use, the filter is easily adopted by any agency regardless of their in-house expertise. While it is subjective, it can, especially if universally adopted, provide a common basis for rapidly excluding most of the unqualified rivers. This is especially true when this filter is combined with overflights, public input, and on-river inspection to determine esthetic qualities. This process can be used to compare and rank qualified and near-qualified streams, those streams that were not chosen for advance study, or streams already in the Wild and Scenic System.

Table 1.--*Numbers of rivers, river segments, and miles of river examined and retained in filters 2-4, and final proposals by State*

State	Water Quality--Filter 2			Development--Filter 3			Field Examination--Filter 4			Final numbers proposed		
	Number of			Number of			Number of					
	Rivers	Segments	Miles	Rivers	Segments	Miles	Rivers	Segments	Miles	Rivers	Segments	Miles
Kentucky	24 (21)[1]	32 (29)	1479 (1269)	21 (5)	29 (6)	1269 (136)	5 (1)	6 (1)	136 (40)	1	1	40
Maryland	3 (2)	4 (3)	164 (49)	2 (1)	3 (1)	49 (26)	2 (2)	3 (2)	43 (31)	2	2	31
Ohio	33 (29)	44 (36)	1862 (1258)	29 (2)	36 (3)	1258 (39)	5 (3)	8 (4)	108 (40)	3	5	48
Pennsylvania	50 (23)	72 (40)	2470 (1124)	26 (12)	43 (14)	1187 (306)	12 (7)	14 (7)	306 (124)	9	9	243
West Virginia	40 (28)	76 (45)	2507 (1253)	31 (16)	54 (20)	1552 (481)	20 (18)	33 (22)	738 (507)	18	23	567
Total	150 (103)	228 (153)	8482 (4953)	109 (36)	165 (44)	5315 (988)	44 (31)	64 (36)	1331 (742)	33	40	929

[1]First number is number examined in each filter, the second in parentheses is number retained.

A MODEL FOR ESTABLISHING WATER QUALITY STANDARDS FOR RIVERS

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ABSTRACT.--An approach is presented for setting water quality standards for a river based on the following functional relation: R = f (Q, CQ, S, RC). Where R = recreation activities (in number of units), Q = water quality level, CQ = cost of achieving or maintaining a specific water quality level, S = recreational supply of the resource, and RC = recreational consumption. The basic assumption was that the recreational use of a river is the most demanding of a high water quality compared to the other uses of the river.

Water quality levels for rivers have characteristically been set by trial and error. Recent technological advances in the field of river water quality, however, now make it possible to explore the possibility of setting certain water quality standards. In this paper we provide an approach for public decision makers to use when choosing a water quality level for a river.

The approach is based on the following relation:

R = f (Q, CQ, S, RC)

where:

R = recreation activities (in number of units)
Q = water quality level
CQ = cost of achieving or maintaining a specific water quality level
S = recreation supply of the resource
RC = recreational consumption

This relation shows that the number of recreational visits depends upon the relation between the overall water quality, the cost of raising the quality of the water (or maintaining a specific quality), and the overall supply/consumption of that particular water resource. The basic assumption is that recreational use of the river is the most demanding of high quality water. The model is analytical but was based upon synthetic data and determined by analogy.

Model development involves three phases of study:

1. Determining water quality of the river.
2. Estimating recreation potential for the river.
3. Calculating alternative costs.

If the decision maker knows the costs the various water quality levels and the mmensurate recreation capacities, he can oose what water quality level and amount recreation supply the river can provide th existing appropriations. Therefore, e model allows the manager to present his cision to those involved with general proval and/or funding in terms of dollars d cents, amount of use, increased water ality, and resource supply, and consumption use of the resource.

PHASE I. DETERMINING PRESENT WATER QUALITY

To determine the existing water quality a river, some definite variables must be stablished as indicators. Examples of inicators in three basic categories and their ssociated specific variables are listed elow:

1. Physical variables:
   a. water temperature
   b. turbidity
2. Chemical variables:
   a. dissolved oxygen content
   b. ammonia content
   c. biochemical oxygen demand
   d. pH
3. Bacteriological variable:
   a. coliform indicators

Criteria for these and other variables re available from the Federal Water Polution Control Administration and from tate Water Pollution Control Boards.

To obtain the above water quality data, ampling stations will be needed. Generally, t is convenient to stratify the river into ones, with a sampling station just upstream f each zone.

After deciding what indicator variables re to be measured and where on the river hey are to be measured, several water uality levels or strata should be determined. his step involves developing a series of ater quality levels ranging from unaceptable to acceptable for each activity or se of the water. These ranges should be onsistent with the kind of recreation acivities involved. For instance, obviously igher quality water is necessary for swimming than for canoeing.

Generally it will be possible to construct these activity-dependent quality ranges by contacting experts in the field, by consulting available research data, and by making some theoretical evaluations. The ranges will vary by activity so it will be necessary to synthetize these quality levels by activity into one complete schedule of water quality ranges. From these water quality levels (table 1), it is possible to observe the changes or increases in water quality that must take place to allow the activities (table 2).

Table 1.--*Water quality parameters (example)*

Variable	Water quality level			
	L_1 (lowest)	L_2	L_3	L_4 (highest)
Turbidity	50	40	30	25
Biological oxygen demand	8	5	4	3
Coliform	800	200	160	120

Table 2.--*Matrix of recreation activities and critical water quality levels (example)*

Activity	Water quality level			
	L_1 (lowest)	L_2	L_3	L_4 (highest)
Swimming	0[1]	0	X[2]	X
Fishing	X	X	X	X
Boating	X	X	X	X
Waterskiing	0	X	X	X
Sightseeing	0	X	X	X

[1]0 Signifies that the specific activity may *not* take place at that level of water quality.

[2]X Signifies that the specific activity *may* take place at that level of water quality.

To construct table 1 pinpoint the lowest (L_1) and the highest (L_4) acceptable water quality levels by variable and by activity. Once these two loci on the water quality spectrum are identified, it becomes a matter of defining proportional levels between the two extremes.

PHASE II. DETERMINING RECREATIONAL POTENTIAL

The recreational potential of a river can be found by following these five steps:

Step 1. Assemble a list of all recreational activities (table 3) that are (1) compatible with the agency's objectives or mission, (2) compatible with the river resources, and (3) have an expected demand not being met elsewhere.

Step 2. Analyze the suitability of the river to accommodate the selected activities. This analysis should include the amount of each activity that can be allowed and the location at which the activities can occur. Generally, a resource inventory will be required.

Specifically, the analysis should provide the following quantitative data: (1) current capacity or production rate, (2) planning period capability, and (3) ultimate capability.

For most land uses, capacity standards will have to be developed to ensure that a quality experience is provided. For example, a given site could have a capacity for 10, 50, 100, or 1,000 picnickers, depending on the quality of experience desired. In fact, when more than one quality of experience can be provided, each should be considered a different land use. For example, family camping and back country camping are two different land uses.

Step 3. Conduct a market analysis for each use to determine need. Need is the deficit of demand after all supplies (suppliers) for a given land use have been exhausted in the land's market area for a given planning period. The market area encompassing the region (distance) surr nd- ing the land from which people would no all take advantage of the use. For example the market area for each land use of a rk will generally be different because the distance people will travel to a given ea varies with the recreational acitvities ey pursue.

Step 4. Calculate the maximized o ut (potential) for the planning period. Ma imized output is the smaller of "need" o suitability. For example, if 100 people want to fish and the river's capacity fo fishermen is 60, the maximized output wo d be 60 fishermen. However, if 50 people wanted to fish the same river, the maxim ed output would be 50 fishermen.

PHASE III. DETERMINING COSTS

The final phase is to calculate the estimated costs for treating the river t maintain the alternative water quality l - els and provide the various recreational opportunities. The costs should include both operating and amortized capital exp - ditures. When Waller[1] applied the model o the Big Muddy River in Illinois, the cos were calculated on a per day basis by zo s. Examples of water treatment costs are pr sented in tables 4 and 5 and recreation costs in table 6.

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[1] *Waller, Louis R. 1973. Water Qua ty Standards as Determined for the Big Mudd River in Southern Illinois Through the Process of Model Development. Ph.D. Dissertation, Southern Illinois University, 200 p., illus.*

Table 3.--*Recreation potential in Zone 1 of a hypothetical river*
(In number of visits)

Activity	Current production level	Potential production level (suitability)	Market area: Demand	Market area: Supply	Market area: Need	Maximized output (potential)
Sightseeing	3,010	40,000	46,746	31,454	15,292	15,292
Boating	10,000	16,316	48,500	27,500	21,000	16,316
Fishing	45,300	121,400	172,145	100,000	72,145	72,145
Swimming	10,000	2,935,082	4,200,000	40,000	4,160,000	2,935,082

Table 4.--*Increment water quality supply costs (example)*
(In dollars per day)

Alternative	Water quality level			
	Level 1	Level 2	Level 3	Level 4
	$ 82	$ 118	$ 523	$ 979
Zones 1, 2:				
Zone 1 - Level 0	255	1,211	2,206	3,012
Zone 1 - Level 1	210	301	870	2,140
Zone 1 - Level 2	210	301	870	2,007
Zone 1 - Level 3	210	301	870	2,007
Zone 1 - Level 4	210	301	870	2,007
Zone 1 - Level 0				
Zone 2 - Level 0	941	4,658	8,539	11,681
Zone 2 - Level 1	941	1,109	3,549	8,539
Zone 2 - Level 2	941	1,109	3,549	8,539
Zone 2 - Level 3	941	1,109	3,327	8,539
Zone 2 - Level 4	941	1,109	3,327	8,539
Zone 1 - Level 1				
Zone 2 - Level 0	941	3,327	7,246	11,238
Zone 2 - Level 1	941	1,109	3,771	8,798
Zone 2 - Level 2	941	1,109	3,549	8,539
Zone 2 - Level 3	941	1,109	3,327	8,539
Zone 2 - Level 4	941	1,109	3,327	8,539
Zone 1 - Level 2				
Zone 2 - Level 0	941	3,327	7,246	11,238
Zone 2 - Level 1	941	1,109	3,771	8,798
Zone 2 - Level 2	941	1,109	3,549	8,539
Zone 2 - Level 3	941	1,109	3,327	8,539
Zone 2 - Level 4	941	1,109	3,327	8,539
Zone 1 - Level 3				
Zone 2 - Level 0	941	3,327	7,246	11,238
Zone 2 - Level 1	941	1,109	3,771	8,798
Zone 2 - Level 2	941	1,109	3,549	8,539
Zone 2 - Level 3	941	1,109	3,327	8,539
Zone 2 - Level 4	941	1,109	3,327	8,539
Zone 1 - Level 4				
Zone 2 - Level 0	941	3,327	7,246	11,238
Zone 2 - Level 1	941	1,109	3,771	8,798
Zone 2 - Level 2	941	1,109	3,549	8,539
Zone 2 - Level 3	941	1,109	3,327	8,539
Zone 2 - Level 4	941	1,109	3,327	8,539

In estimating water treatment costs for the Big Muddy River in Illinois, the various treatments did not affect all the quality variables (turbidity, biological oxygen demand, coliform, etc.) equally. In addition, changes in the water quality variables were calculated relative to the length of flow downstream, the historical variable levels at the sampling locations and the preceding zones water quality level. The water quality needed to safely allow a particular recreational activity to take place in Zone Three and the cost of achieving that level were dependent upon the level of treatment in either Zone One or Zone Two or both. For example, if the historical values for turbidity were 100, 92, and 112 for the three zones, respectively, what would the turbidity value in Zones Two and Three be if Zone One turbidity were reduced from 100 to 50?

Table 5.--*Total water quality supply costs (example)*
(In dollars per day)

Alternatives	Water quality level				
	Level 0	Level 1	Level 2	Level 3	Level 4
	$ 0	$ 82	$ 118	$ 523	$ 979
Zones 1, 2:					
Zone 1 - Level 0	0	255	1,211	2,206	3,012
Zone 1 - Level 1	82	291	383	952	2,222
Zone 1 - Level 2	118	328	420	988	2,126
Zone 1 - Level 3	523	732	824	1,392	2,530
Zone 1 - Level 4	979	1,188	1,280	1,849	2,986
Zone 1 - Level 0					
Zone 2 - Level 0	0	941	4,658	8,539	11,681
Zone 2 - Level 1	255	1,197	1,364	3,804	8,795
Zone 2 - Level 2	1,211	2,153	2,320	4,760	9,750
Zone 2 - Level 3	2,206	3,148	3,316	5,534	10,746
Zone 2 - Level 4	3,012	3,954	4,121	6,339	11,551
Zone 1 - Level 1					
Zone 2 - Level 0	82	1,024	3,409	7,328	11,320
Zone 2 - Level 1	292	1,233	1,401	4,062	9,090
Zone 2 - Level 2	383	1,325	1,492	3,932	8,923
Zone 2 - Level 3	952	1,893	2,061	4,279	9,491
Zone 2 - Level 4	2,222	3,164	3,331	5,549	10,761
Zone 1 - Level 2					
Zone 2 - Level 0	118	1,060	3,446	7,364	11,356
Zone 2 - Level 1	328	1,269	1,437	4,099	9,126
Zone 2 - Level 2	420	1,361	1,529	3,969	8,959
Zone 2 - Level 3	988	1,930	2,098	4,315	9,528
Zone 2 - Level 4	2,126	3,067	3,235	5,453	10,665
Zone 1 - Level 3					
Zone 2 - Level 0	528	1,464	3,850	7,768	11,760
Zone 2 - Level 1	732	1,674	1,841	4,503	9,530
Zone 2 - Level 2	824	1,765	1,933	4,373	9,363
Zone 2 - Level 3	1,392	2,334	2,502	4,720	9,932
Zone 2 - Level 4	2,530	3,471	3,639	5,857	11,069
Zone 1 - Level 4					
Zone 2 - Level 0	979	1,921	4,307	8,225	12,218
Zone 2 - Level 1	1,189	2,131	2,299	4,960	9,988
Zone 2 - Level 2	1,281	2,222	2,390	4,830	9,820
Zone 2 - Level 3	1,850	2,791	2,959	5,176	10,389
Zone 2 - Level 4	2,987	3,929	3,639	6,314	11,527

able 6.--*Recreation supply costs by water quality level and activity (example)*
(In dollars per day)

Activity	Water quality level L_1	L_2	L_3	L_4
Zone 1				
Boating				
Launch	$ 1.10	$ 1.10	$ 1.10	$ 1.10
Parking Lot	.06	.06	.06	.06
Sightseeing		.09	.09	.09
Swimming				
Beach			44.76	44.76
Parking Lot			31.03	31.03
Roads	1.62	1.62	1.62	1.62
Total	2.78	2.87	78.66	78.66
Zone 2				
Boating				
Launch	$ 3.90	$ 3.90	$ 3.90	$ 3.90
Parking Lot	.46	.46	.46	.46
Sightseeing		.30	.30	.30
Swimming				
Beach			45.00	45.00
Parking Lot			41.34	41.34
Roads	8.56	8.56	8.56	8.56
Total	12.92	13.22	99.56	99.56
Zone 3				
Boating				
Launch	$ 3.30	$ 3.30	$ 3.30	$ 3.30
Parking Lot	.19	.19	.19	.19
Sightseeing		.27	.27	.27
Swimming				
Beach			37.30	37.30
Parking Lot			31.97	31.97
Roads	4.02	4.02	4.02	4.02
Total	7.51	7.78	77.05	77.05

APPLICATION OF THE MODEL

Tables 1 through 7 provide a model hat can be used as a basis for making reource management decisions such as:

1. the type and amount of recreation activities that can be allowed, as circumscribed by the considerations of the model, on a river
2. the water quality required for the various recreation activities
3. the cost of obtaining the various water quality levels and providing the necessary support facilities for the recreation activities

The usefulness of the model will be iscussed via two hypothetical situations.

Situation One. Assume that recreational ctivity would take place only in Zone One nd assume that three activities--fishing, oating, and sightseeing--will be provided. o meet the total needs for these facilities it will be necessary to raise the water quality of the river to the L_2 level (table 2) which would cost a total of $121 per day (table 4 $118 and table 6 $3) and would provide the necessary facilities for 103,753 recreation visits throughout the season (table 7).

Table 7.--*Recreation need by activity and zone (example)*
(In number of visits)

Activity	Zone 1	Zone 2	Zone 3
Sightseeing	15,292	50,994	44,980
Boating	16,316	41,307	36,461
Fishing	72,145	187,489	109,547
Swimming	2,935,082	2,951,749	2,445,902

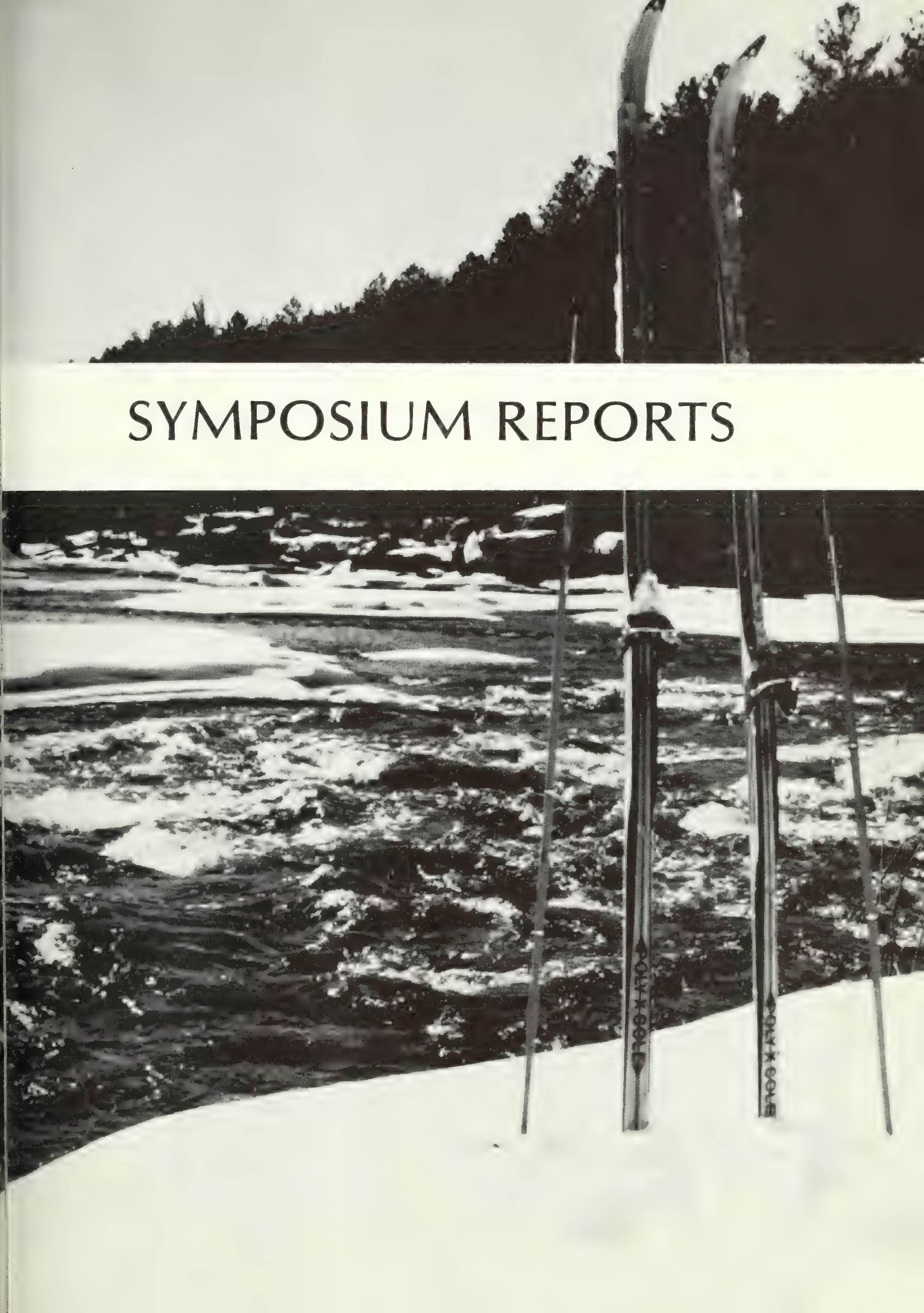
Situation Two. A resource managing agency responsible for the entire river would like to evaluate the alternative costs (per day) for developing the recreational potential of the river. Assuming boating, fishing, and sightseeing will be provided in all three zones, the following data on swimming can be obtained from the model:

Alternatives	*Water Quality Costs (table 5)*	*Recreation Costs (table 4)*	*Total Cost*
No Swimming	$1,529	$ 24	$1,553
Swimming, Zone 1	1,933	100	2,033
Swimming, Zone 2	2,098	110	2,208
Swimming, Zone 3	3,969	93	4,062
Swimming, Zones 1 & 2	2,502	186	2,688
Swimming, Zones 1 & 3	4,373	169	4,542
Swimming, Zones 2 & 3	4,315	179	4,494
Swimming, All Zones	4,720	255	4,975

If the resource agency is limited to a $3,000 per day expenditure, the most favorable alternative would be to meet the total recreation needs except for swimming in Zone 3.

The decision maker could continue to make use of the model on related alternative problems associated with the initial question. For example, for an additional $481 per day or $602 ($523 + $79) per day it would be possible to provide higher quality water and meet the swimming needs (2,935,082 more visits). On the other hand, the decision maker may take the point of view that for $36 less per day, it would be possible to provide facilities and have high enough water quality, (L_1), to allow just boating and fishing.

SYMPOSIUM REPORTS



WORKSHOP #1

STRATEGIES FOR COUNTING RIVER RECREATION USERS

Dorothy H. Anderson, *Associate Geographer*
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About 40 persons participated in the workshop. Leo Marnell's talk, "Methods for Counting River Recreation Users" (published in this proceedings) focused on two major approaches for counting river recreation users: (1) total accounting of all users, and (2) estimation of users. Generally, total accounting, because of the cost involved, is used if there is limited access to a river or if management controls such as mandatory user registration or permit systems have been introduced. The more common method used to measure river recreation use is estimation. This approach requires statistically sound sampling strategies.

Following Marnell's talk, participants discussed current river use monitoring approaches and the direction they believed strategies for counting river users should take.

Reporting systems, surveys, and remote-sensing were discussed as techniques to acquire river recreational use data. Reporting systems include permit systems and user registration. Ground and aerial observation, interviews, and survey questionnaires were mentioned as survey techniques. Time-lapse photography and electric-eye counters were discussed in some detail as remote-sensing methods.

TIME-LAPSE PHOTOGRAPHY

The main topic was the use of time-lapse photography as a means of counting users. One concern was that cameras could be misconstrued by the public as an invasion of privacy. Photography may be legal for counting users but may not be the most politically expedient method. Agencies have attempted to protect the user's rights by rigidly controlling data gathering efforts with cameras. For example, Marnell noted that when studying use along the Ozark National Scenic Waterway, movie cameras were kept slightly out of focus making it virtually impossible to identify any individual. Also, once the film had been developed and counts made, the film was destroyed.

Technology could be developed to computerize cameras so that photographs would be developed within the camera (similar to the Polaroid process) and then transformed by the computer into graphic images plotted and mapped on another medium such as paper, film, or microfiche. In this way, all information except the identity of individual users would be retained.

Participants agreed that the camera is an excellent tool for monitoring river use but improvements could be made in techniques. Rather than simply mounting cameras in stationary positions to record use at particular points along a river, perhaps cameras could be mounted to scan up and down the river and monitor use along an entire river corridor. For instance, if several cameras are used along the same river, it might be possible to synchronize scans and overlap fields of coverage to obtain a complete history of use along the river.

In many situations current technology would suffice because most pictures contain much more information than has been used in past management and research efforts. In Marnell's study, only the number and type of watercraft on the river were analyzed. Those interested in space and time patterns of use within a river corridor could obtain data of this type from photographs. The degree of interaction between different types of groups could also be studied from pictures. Also data on fluctuating water levels and impacts of use on the amount of change in streambank vegetation and the kinds and numbers of wildlife along the shoreline could be examined.

ELECTRIC-EYE COUNTERS

The practicality of using electric-eye ounters to monitor river use was briefly entioned. Three problems in using the lectric-eye counter were noted: (1) the lectric-eye will count two or more boats, ide-by-side, as only one, (2) water level hanges may put the boats above or below he counter's "line-of-vision", and (3) he electric-eye has a limited range.

The first problem could be overcome y using the electric-eye counter with ther procedures such as observation or hotography.

It is possible to modify a photoelectric-ell system so that changing water levels o not affect its operation. When water evels rise, the eye may become submerged nd thus inoperable. The water level roblem could be solved by attaching the ounter to a vertical floating track that ould automatically raise or lower the eye s the water level changed.

Solving the range problem would require esigning a farther reaching electric eye.

OTHER USE-MEASURING METHODS

Unfortunately, there was almost nothing aid about other techniques to count users ven though such methods as human observa-ion, permits and registration systems, nd aerial counting systems were mentioned y Marnell in his presentation. Managers hould be aware of the advantages and dis-dvantages of each of these methods before ttempting to collect use data. Also, anagers should not overlook the possibility of using two or more use-monitoring approaches in conjunction to meet their specific needs. For example, a manager could count the users on a river with electric-eye counters, permits, or a mandatory registration system, and monitor activities at specific river locations by means of time-lapse photography or human observation techniques.

COLLECTING DATA FOR MANAGEMENT NEEDS

A few participants remarked that often-times use data collected for national or regional planning purposes are of little value to managers at the local level. If local manager's needs are known before collection of higher level management data begins, then their goals along with those of a comprehensive data gathering plan can be designed to incorporate all levels of management objectives.

STANDARDIZING USE MEASUREMENT UNITS

One participant mentioned that it was difficult if not impossible to compare use data collected by two agencies because of the different units of measure used. For example, there are at least five ways to describe the length of time a user is in a recreational area. The problem exists chiefly at the national or regional level, rarely, if ever, at the local level because managers seldom need to interpret data another agency has gathered. To resolve this problem an effort to establish stand-ard use units among agencies needs to be made at the national level with input from all agencies responsible for monitoring recreation use.

WORKSHOP #2

CLASSIFYING RIVER RESOURCES AS TO THEIR RECREATION POTENTIAL

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The workshop, "Classifying rivers as to their recreation potential", had two objectives: (1) to create a more thorough understanding of techniques available to assess river quality, and (2) to explore ways in which given methods might be amended to make them more applicable or how they might be changed to reduce cost where less intensive data will suffice.

PRESENTATIONS

The workshop was attended by approximately 150 individuals. Two papers were presented. The introductory paper, "River recreation potential assessment: a progress report", was presented by Michael Chubb and Eric Bauman[1] and appears in this Proceedings under Chubb's authorship. A second paper was presented by invited panelist Louis Hamill, "Development of understandable methods for describing and evaluating the recreational and scenic potential of rivers", and does not appear in this Proceedings.

Chubb and Bauman summarized their paper, focusing most of their attention on the method they developed to assess river recreation potential. The method, called RIVERS (River Inventory and Variable Evaluation for Recreation Suitability), involves assessing 67 physical, biological, land use, esthetic, and accessibility variables for each mile of river and evaluating the potential for 16 recreational activities. They proposed that future work should:

1. Focus on reciprocation and systemization of the technique so it can be applied more easily and more quickly.

2. Include test applications on mo[re] types of rivers, ranging from urban to wilderness.

3. Include test applications where agency personnel undertake the inventory, analysis, and application.

4. Include testing to evaluate continued application in many types of administrations.

5. Include experiments with light aircraft photography.

6. Evaluate various aspects of computer mapping.

7. Determine the relation between the variables used in the inventory and the public's perception of these variables.

8. Evaluate the field cost of application.

9. Evaluate the suitability for incorporating results in management plans and environmental impact statements.

10. Bring together and compile information about the method into a manual to be used in training and in applying the technique in the field.

Hamill discussed background information, major concepts, and procedures applicable to river recreation classification. Over the past 18 months Hamill has analyzed river recreation classification methods developed in the United States, Canada, England, Scotland, and other parts of western Europe. He concluded the state-of-the-knowledge has advanced to the point that it is now possible to develop a set of standardized classification methods. He proposed that the research community analyze available methods to identify those that work and those that do not. It would then be possible to synthesize them into one or more "standard" method.

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[1] *A major portion of the investigation on which the presentation is based were carried out by Bauman while he was a Graduate Research Assistant at Michigan State University.*

Hamill went on to discuss the impor-ance of public participation in the class-fication process and the need for methods hat meet the technical requirements of lanners and managers but that are also omprehensible by the public. He noted hat, "there has been a conflict between hose who favor simple and workable meth-ds and those who seek perceptual and echnical sophistication in concept and rocedures".

From his research Hamill concluded hat the most important information needed o evaluate the recreation potential of ivers may be supplied by methods that:

1. Evaluate the potential for rec-eational use of rivers by paddle and owing crafts.

2. Identify and evaluate the rec-eation potential of rivers for power boats nd sailboats.

3. Evaluate the recreation potential or swimming and beach activities.

4. Evaluate developed recreation ites and facilities in river corridors.

5. Evaluate potential sites for rec-eation facilities and accommodation acilities.

6. Evaluate recreational potential f adjacent land areas for dispersed types f recreation.

7. Describe and evaluate scenery.

He felt it is possible to put together rocedures that will adequately meet the eeds of each of the seven methods. Pro-edures already developed that could pro-ide needed information include the class-fication of rivers based on the Inter-ational Classification of River Levels, lassification of overall difficulty based n the International Scale of River ifficulty, and the classification of skill evels as developed by the Appalachian ountain Club.

DISCUSSION

Participants voiced concern about the ost of using a technique, such as the IVERS Method, especially the high cost of surveying each 1-mile segment of a river. Chubb noted, by analogy, that other resource inventories and classifications are routinely conducted and they too are often expensive. He concluded that the importance of rivers as recreation re-sources will be recognized and funds allocated for more inventory and classifi-cation surveys in the future.

Participants questioned whether a method developed in one area of the country would be applicable in other areas. Discussion pointed out that classifica-tion schemes should have capabilities over a wide area and should be flexible enough so that, with some modification, they could be used on a large scale throughout the continent. The RIVERS Method needs further testing in areas outside of the Midwest to determine its suitability for other regions.

Public participation in the formal designation of rivers (Through Federal and State programs, for example) was discussed, especially in terms of the level of public participation during the designation process. No real conclusions were reached, but, Hamill noted that the public should be provided with detailed information at all levels of the designation process if public participation is to be useful.

Some participants felt that classifi-cation schemes should utilize data col-lected for other purposes, such as wildlife habitat management. Hamill, Bauman, and Chubb agreed that any method should be able to accommodate such information, but, cautioned that such data are often collected with rather broad objectives and hence may not be reliable.

SOME THOUGHTS ON RIVER CLASSIFICATION

Much attention has been given to developing classification schemes purporting to identify those attributes of rivers that are significant in assessing their rec-reation "value". An intensive search of the literature on river classification, evaluation, and assessment revealed at least 50 studies that focused on these topics. Chubb and Hamill, in this Proceed-ings, reviewed a number of these techniques. Other papers in the Proceedings including Doehne, Branch and Fay, Borden, Kuska, Pfister, Walker, and McCurdy testify to

the importance of such procedures for planners and managers.

Most of the classification schemes utilize physical, cultural, or esthetic features of a river or a river corridor. Nearly all divide rivers into small segments rather than attempting to classify entire waterways or drainages. Unfortunately, most schemes do not incorporate the river's location relative to population centers or alternative recreation resources. Also, they tend to overlook the legal attributes of rivers in terms of recreation development potential.

Most classification schemes focus on remote river resources. The more general purpose rivers--those more to the center of the river recreation opportunity spectrum--have received much less attention. And, schemes to evaluate and classify urban rivers have received little or no attention. Assessment of urban river recreation potential could help alleviate pressures on other rivers serving a more specific recreation purpose.

Some evaluation and classification schemes have utilized peoples' preference for water-based landscapes. Most of these techniques relied on peoples' reaction to slides or photographs of various scenes. Results obtained in this manner should be used with caution. For example, consideration should be given to the social/cultural backgrounds of the respondents. Dearinger *et al.* (1973) noted that people generally agree on what is very beautiful and very ugly but not on the in between, and that occupation and lifestyle have an effect on individual concepts of natural beauty.

RESEARCH AND RELATED NEEDS

We hope this workshop established a point from which new and more dynamic research may proceed. Several topical areas that I believe need research consideration are listed below. The items mentioned are not all inclusive nor are they ranked in order of priority, but I feel research is needed to:

- Incorporate the concept of social and biological carrying capacity more fully into evaluation and classification schemes.

- More fully determine the attribu of rivers that are important to people i their pursuit of river recreation (see Cherem and Traweek and deBettencourt and Peterson in this Proceedings).

- Incorporate data from studies of user perception into evaluation and clas ification schemes.

- Develop computer techniques that will store, retrieve, and graphically di play classification and evaluation data.

- Develop simulation models that describe the effects of alterations of river resources, such as timber harvesti stream channelization, mining, etc. These models should be capable of provid reasonably accurate predictions of how environmental changes affect the recreat potential of river resources.

- Objectively analyze the state-of the-knowledge--about river recreation cl ification. (Hamill is currently working on this).

- Develop techniques suitable for classifying urban rivers.

- Develop techniques that allow fo more accurate assessments of public participation in formal river recreation designation efforts. For example, techniques are needed to determine if th views of vocal citizen groups are representative of the more general public and what value should be placed on public input.

Throughout the Symposium a reoccurr theme was that there is an "explosion" occurring in river recreation use. This explosion has placed enormous pressures on management agencies and has presented a tremendous challenge to researchers an other concerned persons. Roderick Nash, in his opening remarks admonished Sympos participants that river recreation manag ment in the future will be challenged wi the task of keeping the options open for Americans and matching a particular environment to its optimum use. This *is* a formidable undertaking. But if there to be high quality and diversified river recreation opportunities in the future, will be because of what we are doing tod

WORKSHOP #3

STRATEGIES FOR STUDYING RIVER RECREATION USERS

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There were too many people present (100) to allow the meeting to function as a true workshop. Rather, what was held was a subsession of the conference in which the focus was on a single formal paper with more opportunity for questions and discussion from the floor than in a general session.

EXPECTATIONS FROM THE AUDIENCE

The workshop participants expressed concerns in the following areas:

1. Correlation between the human psychological response to the physical environment and actual conditions of the physical and visible environment.

2. Methods for defining and differentiating among different types of river users.

3. Measurement of users' needs, including identification of the most successful strategies for measuring needs.

4. Methods for assessing or predicting user-related problems before they occur, so that users can be managed and problems prevented.

5. Methods for identifying and describing conflicts among different types of uses.

6. Strategies for measuring use in different environmental settings and under different intensities of use.

7. Strategies for integrating the methods and findings of different sciences and different scientists.

8. Methods for measuring and predicting trends or shifts in user needs.

9. Nonreactive methods.

DISCUSSION OF ROGER CLARK'S PAPER

The Clark paper serves as an excellent framework for discussing different approaches for obtaining information about recreationists. It is well conceived, thoughtfully organized, and clearly written. It should be studied carefully by anyone in or about to enter the business of collecting data for management or study of recreationists. The framework could well be recommended as a guide for the wise and a law for the weak. To those who are experienced, mature, and wise in this kind of research, the Clark framework is a welcome organizer of concepts and the associated commentary is a useful review. There is danger, however, of oversimplification and unnesessary limitation, if the creative and responsible researcher feels compelled to work strictly within the limits of any framework. On the other hand, the inexperienced or untrained would do well to pay strict attention to the paper. There is simply too much sloppy, inefficient, and misleading information drifting about.

The central issue is, of course, that information gathering methods should be designed to meet the needs of the researcher or manager in need of the information. The information should be valid and reliable. The methods should be cost-effective and should address efficiently the questions being asked. It should be recognized that a given problem may have unique requirements that call for creative techniques. In some cases, special restrictions may force the researcher to use methods that otherwise might be inferior. The important questions are: (1) is this the *best* method that can be used under the circumstances, and (2) are the products useful and worth their cost? Sometimes it may be advisable to use several methods that can be cross-checked for validity and reliability.

One type of methodology that may not fit well in the Clark framework is the simulated choice experiment. This is an experiment in which the recreationists' choices are observed in a simulated situation, e.g., among photographs, verbally described alternatives, etc. It is tempting to sweep such techniques into the general box of self-reports. In fact, such methods are a special type of direct observation. Reliable measurements can be made by such methods, and, under certain conditions, the results can be shown to be valid. However, to design such a method is a highly technical undertaking.

Another kind of technique not easily fit into the framework is illustrated by the so called "ink-blot" test and the "Environmental Response Inventory". In these tests, the subject responds to carefully selected stimuli that have been selected through extensive research for their ability to differentiate among people who tend to behave in different ways. Indeed, we have much to learn from other disciplines, e.g., psychology and marketing, where researchers have been working for many years to develop specialized methods for describing and predicting various aspects of human behavior.

The presentation and ensuing discussion from the floor emphasized the following issues:

(1) nonreactive measures; (2) longitudinal techniques; (3) coordination of different methods; (4) weaknesses in self-report methods; (5) the importance of efficient sample design; (6) the potential usefulness of secondary data sources, such as information in license and permit files, sales records, etc.; (7) problems of invasion of privacy; (8) use of deceptive research methods; (9) the political and public relations effects of different research methods; (10) the need for cross-validation by means of several methodologies; (11) the need for researchers to get their act together so as to present a more coherent and legible interface to the managers who want to apply their work; (12) the need to recognize that study planning should be a continuing process of improvement; (13) the too prevalent tendency to "cop-out" and use "traditional" methods such as self-report surveys without examining critically whether the best or even good methods are being used; (14) the need for familiarity with the limits and capabilities of a variety of strategies so that alternatives can be considered intelligently; (15) the need to be sensitive to the important management needs; and (16) the need to understand the limitations of the data produced by a given method or a specific study so as to avoid over interpretation.

MISCELLANEOUS REFLECTIONS

To describe and explain human behavior is not easy. Too often the phenomena are so complex that order cannot be found on which to build a theory, or the variables are not accessible and apparently cannot be defined in ways that allow them to be observed and measured, or the needed experiments and observations cannot be made because they would violate ethical principles. Thus, when we criticize recreation research, we should distinguish between inadequacy caused by the nature of the problem and inadequacy caused by careless or incorrect methods. Because of the demanding nature of the task, we can excuse conflicting conclusions or missing facts when these are not the fault of undisciplined work. But undisciplined work is not excusable no matter how difficult the task. Indeed, to climb Mt. Everest requires much more skill, specialized equipment, stamina, and determination than to climb Pike's Peak. One cannot excuse the failure of a poorly planned assault on Everest on the grounds that the objective is difficult to achieve. The added difficulty of the task is reason to demand the highest qualifications of those who try. But even with the best possible planning, the probability of failure on Everest is much higher than on Pike's Peak, and Pike's Peak was climbed long before Everest was.

Observation of human behavior and measurement of things such as perceptions, motives, etc., are highly technical undertakings. If you want valid and reliable results, you don't just throw together a questionnaire and go do a survey. Clark has emphasized this in his paper and has given us a primer on research methodology. But even with this primer in hand many specialized skills are needed before the job can be done right. Would-be researchers would do well to recognize this and get special help when entering areas beyond the limits of their competence.

It also needs to be recognized that

there has not been a lot of money focussed on recreation research. Support has been meager and disjointed. Too often we have had to make do with inadequate resources, and recreation research has had to accept amateur status. Here we must differentiate between (1) good work that is of limited value because of financial malnutrition, and (2) poorly conceived and executed research.

Another source of confusion about the quality of recreation research is the problem of the conflicting objectives of applied and basic research. To the resource manager faced with everyday decisions, highly specialized, theoretical research is not of much value until it is translated into applicable facts, principles, or procedures. On the other hand, applied research is often disdained by theoretical purists. Clearly, it would be a mistake to require all research to be theoretically pure. Somebody who understands both the practical problems and the esoteric theory has to do applied work. It would also be foolish to require all research to be strictly directed to some specific practical problem of resource management. A diverse spectrum of applied and theoretical work is needed, but such a spectrum of diversity is likely to foster, as it has, some confusion and controversy, because individual scientists generally cannot see the whole picture.

A problem that may always be with us is that individual researchers have traditions, prejudices, and attachments that tend to bias each toward a peculiar modus operandi. Such a researcher who attacks only those problems to which his "trick" is applicable is more defendable than one who applies his trick to whatever problem comes along without questioning the appropriateness of his approach.

This kind of problem is compounded by the immaturity of the field. There are good sociologists who apply sociological methods and traditions to the social facets of recreation. There are good psychologists who apply psychological methods and traditions to the behavioral aspects of recreation. But there seems to be no established discipline of recreation research with an associated baggage of time-tested methods and accumulated traditions. On the one hand this is good, because it enhances the probability that problems will be attacked creatively with fresh perspective. On the other hand, the risks and hazards are greater. The traditions of a scientific discipline are an accumulation of successful strategies, culled and evolved through a process of trial-and-error, state-of-the art review, and rigorous criticism. There is and has been a lot of disjointed trial-and-error going on in recreation research. Whether we will ever get ourselves together some day remains to be seen, but in the meantime we do need more contributions (like the Clark paper) that propose frameworks, and identify and scrutinize alternative research strategies. This kind of work helps guide researchers toward good methodology, and it encourages badly needed standardizations, which, in turn, enhances comparability among studies.

The Symposium in general was a valuable exposure to a rich diversity of viewpoints on river recreation management and research. A lot of ideas were exchanged, and, it is hoped, many minds were broadened. But the experience was not without its frustrations. There was a little too much "holier than thou" preaching about the virtues of wilderness, with resulting polarization, and not enough rational deliberation about the value of preserving variety of choice, about the fact that wilderness resources are scarce and will disappear from the spectrum of choice without appropriate intervention, or about the fact that there are many substitutes for the uses that compete with wilderness recreation and few if any substitutes for the wilderness uses.

There was a little too much detail about legal technicalities and not enough perspective about the role of law and legislation in river management.

There was a little too much advocation of special interest points of view and not enough recognition of the need to separate technical matters from political or ideological issues. We have a system founded in the constitution that provides for a nonviolent alternative to war for resolving conflicts that are arguable on ideological grounds or that involve competition among individuals for limited resources. That alternative is the political-legislative-judicial process, and that process comes to its own conclusions. I perceived that there was a tendency on the part of some participants to argue for technical solutions to political problems, which would preempt rights belonging to the people.

There was a little too much hasty presumption that the answer to each problem is some sort of management by the government. Government intervention may prove to be the best answer in each case, but there seemed to be too little readiness to ask whether there might be some self-regulating market processes that might solve the problems, or whether the issue is properly a matter of private conflict that is more appropriately resolved through litigation and judicial review, or whether there were deficiencies in the legal framework that need to be corrected legislatively.

There was a little too much discussion of rivers as if they were owned by government bureaucracies rather than being owned by the people by whose consent our government exists and from whom the bureaucratic rights and powers are derived.

There was too much myopia, as if it were a symptom of ignorance of (or unwillingness to consider) the many facets of each problem.

There was a little too much preoccupation with remote and wild recreation opportunities and not enough concern for the masses of people who are captives of the urban way of life with little opportunity for access to the idyllic river resources.

There seemed to be too little conce for the implications of an uncertain fut that teeters precariously on the whims c unpredictable and uncontrollable climati trends, disappearing energy resources, a economic malaise.

There was too much preoccupation wi the mystique of being alone in the wilde and not enough attention to the reasons people are concerned about encountering others on a river and the situations in which the concern becomes significant.

I guess what I am trying to say is not that it was a bad symposium. It was an excellent symposium, one of the best conferences I have attended. But it was like a bag of jigsaw puzzle pieces, all mixed up from many puzzles, with some pieces missing, and no pictures to follo in trying to sort out the pieces and put them together. Somebody should have written, and should still write, an integrating paper that provides a framewor of planning theory and social policy issues that would help us to organize a well balanced attack on each question.

WORKSHOP #4

RATIONING RIVER RECREATION USE

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The rationing of access to recreational esources is a recent phenomenon, a result f steadily increasing use pressures, oupled with dwindling supplies. Rationing s generally seen as a means of controlling esource impacts and loss in recreational uality. But rationing what traditionally as been a "free" resource--even a right o some--has been controversial and dif-icult. Questions of how, when, and where o ration resources plague managers, and heir best answers have been often crit-cized as arbitrary and capricious. In ome cases, the courts have been approached or redress to real or imagined hortcomings.

The paper of Sam Warren outlines the ationing system that managers on the iddle Fork of the Salmon River in Idaho ave adopted. In brief, the system uses lottery for distributing "places" and hese are distributed among commercial out-itters and private river runners. Appli-ations are accepted from users with three hoices of dates permitted. A lottery is eld in February and successful candidates re notified by mail. A maximum of seven aunches per day is allowed. Parties who rrive at the river without a permit either because they are unaware they need ne or because they simply hope to "beat" he system) can obtain permission to launch heir craft provided the limit of seven aunches per day has not been exceeded. arren notes that while 150 private permit pplications had to be turned down in 976, commercial allocation quotas were not illed. Thus, the issuance of permits to drop-ins" can prevent underutilization f the river resource. However, the system as been criticized by commercial and rivate river runners alike, a fact videnced by Warren's estimate of the hreat of one lawsuit per month directed t the rationing program.

The rationing program on the Middle Fork is founded upon three fundamental assumptions: (1) the USDA Forest Service will seek to maintain a healthy outfitting industry; (2) the permit system should give all persons a fair and equitable chance to run the river; and (3) the system used must be within the budget and personnel limitations of the agency.

Some criticism during discussion was directed at these assumptions. Forest Service support of the outfitting industry was seen by some as unnecessary at best and as discriminatory to the interests of private river runners at worst. Although it was not made explicit during discussion, the Forest Service's support of this commercial interprise appears to have its roots in broad Federal statutes supporting rural development and local economies. Although the extent of Forest Service support and the specific types of economic activity involved might be debated, the general assumption the agency has taken with regard to the outfitting industry appears to be legitimate and proper.

Much discussion centered on the specific mechanisms that might be employed to ration use. Concerns with equity and fairness were expressed by many participants. However, there seemed to be considerable confusion over the issue of rationing as opposed to the issue of allocation of use permits. Rationing, which was the focus of this session, centers on the mechanisms through which opportunities to use the river system are distributed to users. Allocation concerns the relative proportion of the available openings given to different clientele groups; e.g., commercial outfitters versus private river runners. The distinction between these issues is important. Rationing is a complex problem, but the choice of mechanisms is an issue

that is substantially within the prerogative of the manager. Management experience, research data, and good judgment can be used to improve the delivery of services to people. Allocation, on the other hand, is an issue that deals with the normative question of "who should get what" and, as such, is an inherently political issue, largely outside solution by managers and scientists.

With specific regard to rationing, several important points were raised. First, there is a range of rationing mechanisms that managers might consider. For example, solutions suggested by participants included entrance fees, lotteries (the present Middle Fork rationing program is a lottery), and user licenses.[1]

Second, it was recognized that any rationing system has shortcomings and can be "beat"! As mentioned above, people who arrive on the Middle Fork without a permit can still obtain one by waiting until the daily launch limit of seven crafts is not reached. While this is a safeguard against underutilization, and can help accomodate visitors who are legitimately unaware of the rationing program, it also opens an avenue to people who do not want to deal with the system. One participant suggested private river runners have a greater opportunity to "beat" the system because commercial river runners must operate under a special-use permit issued by the USDA Forest Service and are therefore more closely regulated. However, Sam Warren pointed out that outfitters can affect demand for their services through advertising.

Third, several participants stressed the importance of providing a range of options for users, both in the kinds of recreational experiences that rivers provide and in the regulatory measures used by managers. Al Wagar of the USDA Forest Service made an especially important poi[nt]: it is imperative that our management programs be conceived within the framework of a *system* of opportunities. Wher[e] our horizons are restricted to an area-b[y-area] area perspective, decisions as to what kinds of experiences are to be provided and what management techniques are to be used can quickly become tangled in a web of concerns about appropriateness, equit[y] and utility.

Finally, participants recognized th[at] rationing, defined as the direct control of use through regulatory measures, is only one of the management techniques available to managers. Other sessions o[f] the symposium dealt with these measures, but in general, discussants agreed that many nonregulatory measures exist that should be considered for controlling impacts on rivers before direct regulation is instituted. In Michigan, for example managers have utilized design features to control impacts. Camping sites have been kept away from river banks, access to rivers has been controlled to prevent random entry, and litter control measures have been instituted. However, it was clear that some of these measures are simply not feasible on all rivers. On the St. Croix River, for instance, most of the access points along the 252 miles of the river a[re] not under control of the managing agency. Where possible, nevertheless, participants agreed that management should institute only those measures necessary to achieve the desired end, rather than automatically implementing rationing.

The third fundamental assumption underlying the rationing system--that it must be within the budget and personnel limitations of the agency--is a real world constraint that is frequently forgotten in a world increasingly tied to computers, sophisticated programming, and related electronic wizardry. While such tools and techniques do offer great promise in grappling with difficult resource management problems, we need also remember that many programs and policies are implemented at field levels where, as Sam Warren noted the manager feels lucky to have a telephone and desk calculator.

One important by-product of the rationing program on the Middle Fork has been the development of accurate, up-to-date management information. Estimates

[1]*Two other generic rationing systems, queuing (first-come, first-served) and reservations (a variant of queuing, with future rights to openings assigned to people by pre-registration) drew little discussion. However, the assignment of permits to drop-ins when daily launch limits have not been reached on the Middle Fork represents, in essence, a queuing approach to rationing.*

of use--how much, what kinds, when, and where--notoriously bad in many of our lispersed recreation settings such as wilderness, have been greatly improved by the permit system. In addition, because the USDA Forest Service issues all permits to river runners, private and commercial, there has been an excellent opportunity for informational contacts with visitors concerning river management policies. This two-way interaction between manager and user all too often is missing in many of our recreation areas and probably helps contribute to the misperceptions of each group about the other. Important management objectives can be often achieved by obtaining public understanding, thereby reducing or even eliminating the need for more direct restrictions. For example, Warren noted that when the rationing program was first begun, visitors were issued litterbags which were then checked by rangers after completion of the trip to determine compliance with pack-it-in, pack-it-out regulations. This check on visitor behavior has now been dropped because litter clean-up has become the norm among river users.

What of the future? Both Warren as well as most symposium participants see increases in use on the horizon. The explosion of use on America's rivers has truly been staggering, as several papers in the proceedings graphically attest. The growth in use is almost certainly more than just a fad; it is unlikely we will ever again see the level of use on the country's rivers that prevailed a decade ago. At the same time, it seems important that we obtain as accurate a grasp on the growth phenomenon as possible. For example, it is a common assumption that official designation (e.g., establishment as a Wild River) is, in a sense, a "kiss of death" because it makes the area a target for "trophy" collectors. This is certainly a plausible notion; naming an area officially probably does promote recognition. However, it could also simply reflect the greater attention that managers must now give to the area in question and the often-cited spectacular increases in use might be largely a result of the belated recognition of use conditions that have prevailed for some time. Separating conventional wisdom from fact is an important responsibility of managers, researchers, and users alike, as we attempt to place scarce management dollars and skills in the most deserving places.

Participants questioned the future role of the commercial outfitters on the Middle Fork. In the opening remark of the question period, Joe Hoffman of the University of Idaho proposed de-regulation of the commercial outfitting industry. The USDA Forest Service would retain control over the total number of users permitted on the river and would set safety standards with which outfitters would need to comply. Visitors obtaining permits would be free to choose running the river on their own or with an outfitter. In this way, Hoffman argued, market place mechanisms would lead to the proper number of outfitters on the river. His argument was countered in later discussion, however, by an individual who argued that deregulation would not necessarily lead to the survival of the "best" outfitters. Success, it was argued, would be largely a function of capitalization, and large, well-funded outfitters would enjoy an advantage over smaller entrepreneurs. Thus, outfitters specializing in unique styles of river running that appeal to only a minority of visitors would probably be forced out of business.

Conditions on the Middle Fork will almost certainly change in the future. Warren agreed that political pressures might eventually force shifts in the allocation of permits between private and commercial sectors. The notion of "percentage of disappointment" raised by Rod Nash of the University of California at Santa Barbara represents a plausible alternative for re-establishing the allocation ratio. Given the problems of "no-shows", for whatever reason, Warren estimated that 80 percent of capacity will probably be the maximum level of utilization to ever occur. As noted earlier, demand from private runners exceeded their allocated capacity while commercial users have underutilized theirs. Revisions of the private-commercial allocation should be sensitive to this relation as it provides a logical basis for reassignment of the ratios. However, a very real future possibility is the exclusion issuance of individual permits, dropping the commercial-type trip altogether. Constant monitoring and reassessment of policies and programs seems absolutely necessary if the USDA Forest Service is to avoid being caught in the position of managing the river with a set of assumptions and mechanisms that are simply out of touch with changing realities of use.

RATIONING--AN OVERALL ASSESSMENT

As the discussion above suggests, many specific ideas and general impressions surfaced at the session. Summarizing them all into some cohesive and logical fashion is difficult, but it seems to me that several issues warrant specific recognition.

First, rationing seems to have fair public support as a legitimate management action. Much of the debate over its use centers on how it is applied, where, and so forth, but most users appear to agree that rationing is an appropriate action to protect river resources and recreational experiences.

However, my second impression is that misuse of rationing might jeopardize its use as a management tool. A range of visitor management actions needs to be considered--from subtle, light-handed techniques such as providing information to people about alternative opportunities to more restrictive actions such as regulation of access. In choosing what measure is appropriate in any given sitiation, the lowest level of regulation necessary to achieve area management objectives should be instituted--the principle of minimum regulation. In other words, if visitor impacts can be held within acceptable limits simply by providing information to users, it would be inappropriate to use any more restrictive measure, such as rationing.

One can even visualize this type of variability within the rationing measures themselves. For example, there was considerable discussion about the idea of regulating use by the issuance of licenses--rationing by merit. Such a measure would require users to pass some kind of test (e.g., demonstration of knowledge, skill, or both). One implication of such a measure is that by raising visitor skills, thereby reducing per capita impact, the need for absolute restrictions on total visitor numbers could probably be postponed. In effect, improving visitor behavior could raise an area's carrying capacity.

This leads me to a third observation. I am struck by the lack of clear management objectives for rivers to help guide management actions. One participant noted that the perception of what kind of experience rivers produce differs between managers and users. Moreover, there were varying notions about what benefits rivers, even those within the Wild and Scenic Rivers System, should provide. However, the general concerns about solitude and naturalness suggest that many hold a wilderness-bias with regard to what kind of experiences rivers should yield.

The lack of clear objectives means these personal biases as to what river experiences should be provided can be substituted for more formal specification of goals. From this, it is an easy step to assuming that *any* increases in use or *any* increase in resource impact constitutes a loss of quality that can be counteracted only by the relative drastic action of directly rationing use. Such a step is unwarranted and creates an undesirable set of conditions for managers and users alike.

Rivers, like any recreational resource system, can and should provide a satisfaction for people seeking a variety of experiences--from those dependent on intense social interaction to those that rely upon isolation for their fulfillment. This can only be achieved, as Al Wagar suggested, by considering rivers within the context of a *system of opportunities* rather than simply on a river-by-river basis. By managing on a regional basis, with the system of rivers specifically managed to yield a package of diverse experiences, many of the concerns about equity can be more easily addressed.

We also need to consider visitor management and rationing from a regional perspective. With a broad range of opportunities, represented by a system of areas with differing management objectives, a range of visitor management techniques will be necessary and appropriate. Thus users will have a broad range of choices-not only of opportunities suited to their particular tastes but also of the level and nature of managerial control. This diversity seems absolutely necessary if we are to meet our responsibility as professional resource managers to the American people.

One of the major concerns about rationing is that some people will always find themselves discriminated against by the system. My fourth observation is simply this: any rationing system discriminates against certain people; in fact, it is this discriminatory feature

that makes rationing work. If it didn't, what good would a rationing program do? The relevant question is not how to prevent rationing from being discriminatory, but rather, how to spread those discriminatory costs across the spectrum of users?

Again, a system of areas can help us spread these costs. The objective should be to make sure that when rationing becomes necessary, the specific techniques utilized (e.g., lotteries, merit, fees) should vary among areas so that users are able to make choices that allow them to accommodate the rationing costs in the best way. For example, reservations discriminate by favoring those able, willing, or both to plan for the future; fees discriminate on the basis of who is able or willing to pay the monetary costs, etc. Each system favors certain groups and discriminates against others. By providing a system of areas where rationing mechanisms vary, the effect should be to minimize aggregate equity costs.

Finally, I was struck by the virtual absence of any discussion about river carrying capacity. Rationing implies that some finite number of openings has been reached and because of excess demand for those openings, some mechanism for distribution has to be implemented. Thus, rationing hinges on the integrity of the carrying capacity calculations.

Although carrying capacity was not discussed in this session, it is clear that rationing decisions will be challenged increasingly in the future, and these challenges will be often tied to the carrying capacity estimations made by managers. Carrying capacity is ultimately a judgmental issue and managers, researchers, and citizens alike all have important roles to play. Managers define the various constraints they must consider and are charged with making the final judgments as to what constitutes acceptable consequences in light of these constraints. Researchers must supply clear measures of the consequences and implications of alternative use conditions so managers can make decisions based on reasonably accurate estimates. Citizens have the responsibility to make their views and values known as well as to make judgments about the trade-offs they are willing to make. Only through open dialogue among these three groups can the complex issues of rationing, carrying capacity, and river management be adequately resolved.

WORKSHOP #5

METHODS TO CONTROL NEGATIVE IMPACTS OF RECREATION USE

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The "negative impacts" workshop emphasized problem identification and methods for control of physical and social impacts on wild and scenic rivers. Impacts on other rivers, where recreational opportunities are more variable and possibly more complex, were generally ignored. Unfortunately, problem identification, research needs, and management procedures covering the full spectrum of river recreation were not developed during the session. Certainly this omission does not reflect either disinterest on the part of managers and researchers or the absence of problems associated with nonwilderness river recreation.

SOCIAL PROBLEMS

"People management" surfaced as a key issue. William Craig, the introductory speaker, and several other participants emphasized the serious consequences of failing to gain local support before establishing wild or scenic rivers. Lawrence Merriam called river use a "social activity", and suggested that designating a river as "wild" changes its use and displaces many predesignation users--mostly local people. For example, wild river designation leads to road closures in the reserved corridors. Local residents who customarily used the roads resent and resist the closures unless the value to them of establishing a wild or scenic river can be demonstrated. Craig reported cases where trees were felled or wires were strung across rivers to impede traffic, often capsizing boats. Locals then charged fees to recover equipment lost in the river. Shooting at recreation equipment has not been uncommon; facilities of all types have been defaced or destroyed; four-wheel-drive vehicles, trucks, and motorbikes have been used to circumvent closures; and incendiarism has more than tripled following road closures. Such vandalous public reaction is difficult to stop where roads are publicly owned, and i is virtually impossible to control where river access is over numerous privately owned roads.

Coping with acts of vandalism is extremely complex becuuse guilty persons are nearly impossible to identify (Alfan and Magill 1977). Fortunately for river managers, local people, as a group, have been recognized as responsible for acts perpetrated following wild and scenic rive designations. Several managers and researchers suggested that all aspects of wild and scenic river proposals--in fact, any river management proposal--should be thoroughly discussed with local residents and its importance *to them* should be clear specified to gain their acceptance before any action is taken. This approach is supported by social scientists who general agree that increasing two-way communicatio between managers and users, building more effective educational programs, and devisi means for gaining public involvement are necessary if vandalism is to be effectivel controlled (Alfano and Magill 1977). However, even carefully planned public involvement programs are unlikely to convince everyone; some problems will still obtain, but hopefully they will be fewer and less serious.

ROAD CLOSURE MECHANICS

William Craig, in his introductory paper, suggested constructing double barriers of earth ranging from 7 to 10 feet high to stop unauthorized use of closed roads. This solution may be effective, but it is also obtrusive. An obvious reaso for designating rivers as wild or scenic is to preserve visual quality, not only along the river but throughout the preserve area. Thus, effective but visually acceptable road closure techniques are desirable. Heavy-duty steel gates with steel lock

ages and posts anchored in concrete are proven alternatives which are less obtrusive. A workshop participant offered an innovative alternative: blend the closed road into the surrounding forest--make it disappear by establishing a new segment of forest. A mechanical tree planter can be used to extract trees from nearby land and replant them in the roadbed. Sufficient numbers must be planted to completely conceal the road, and stumps or logs and forest litter may be added to provide a finishing touch.

WASTE DISPOSAL

Waste disposal was another serious concern of workshop participants, and most concern was with disposal of human excrement during boat trips. The ultimate solution may be designation of "no discharge" streams where sewage disposal is totally prohibited regardless of treatment levels. Boats may be required to carry portable toilets to be emptied only at designated locations. Dumping is sometimes allowed on large beach areas provided a deep pit is dug and covered. Stewart Aitchison reported such procedures are used in the Grand Canyon of the Colorado River, but said beaches with high clay content fail to absorb liquids. Obviously, such locations must be identified and avoided. Fecal coliform bacteria tend to remain at high levels in beach sands for more than a year according to Aitchison. This suggests that self-contained toilets may need to be dumped at the end of trips to avoid creating health hazards.

Contamination of soils and waters by liquid cooking wastes is another problem addressed by Aitchison. Such wastes make beaches smell bad and attract insects, birds, and other animals. Some animals attracted to the beaches are in poor health and may be hazardous to humans.

Litter and trash pose expensive cleanup problems along all types of rivers just as on land used for dispersed or developed recreation. In wilderness areas, including wild and scenic rivers, the "pack it in, pack it out" policy seems to be gaining in success, but more public educational efforts are needed. "Riverside" cleanup trips may prove useful just as have wilderness cleanup trips, but prevention is the better solution. Providing litterbags helps prevent onsite refuse disposal, but does not encourage pickup of existing litter (Clark, *et al.* 1972). Research indicates that incentives may be offered to encourage pickup in campgrounds, but the method seems less plausible along streams.

SOILS AND VEGETATION

Human impact on the soils and vegetation along rivers and methods for controlling it received little attention during the workshop. Yet, retaining soils and maintaining vegetative cover along streams and in watersheds are essential for insuring water quantity and quality, maintaining forest visual integrity, and providing an attractive and useful refuge when river users choose to rest.

Aitchison, speaking of the Colorado River in the Grand Canyon, aptly said that the most heavily used areas are not necessarily the most heavily impacted. The reason for this anomaly may be attributed to variation among resources and users. Some resources may exhibit greater resistance to heavy use, and the actions of different users may impact resources more or less severely. Additionally, managers who are unfamiliar with local plants, soils, and wildlife or the interactions between resources and people may not recognize subtle changes in river ecosystems that indicate the need for increased resource protection or remedial action. These observations are valid for other rivers regardless of intensity of development and use as well as for nonriver recreation areas.

Damming the Colorado River has prevented scouring of river bars and beaches with resultant increases in native and introduced vegetation, according to Aitchison. New growth provides food and cover for wildlife as well as screening for campers, but as the vegetation continues to increase it encroaches on usable camping space. When that happens, trampling and cutting prove beneficial by restricting growth and spread to acceptable levels.

Damming the river has also caused a scarcity of firewood because flood waters previously carried it down and deposited it on the beaches. Without a replenished supply of firewood, river runners will need to carry portable stoves.

In his paper, William Craig said compacted soils are one of the major user impacts, and they must be cultivated. However, his advice should be weighed against soil characteristics and plant and soil relations. Several studies have shown that soil compaction may prove beneficial by effecting greater root firmness and increasing growth rates through increased supplies of soil moisture and nutrients and reduced microflora competition for nitrogen (Lull 1959 , Hartesveldt 1963 , Magill and Nord 1963). Bare areas around tables and stoves and in tent sites become dusty and are particularly annoying on windy days. Mulching with forest litter or applying clear, nontoxic, chemical dust control agents may control dust, thereby avoiding the alternative of spreading such unnatural appearing materials as hay or pea-gravel.

Eliminating vegetation is another major impact on recreation sites. As Craig noted, research and experience gained from protecting and restoring vegetation in wilderness and lake areas can be adapted to river management. In addition, research done by LaPage (1967), Magill (1970), Echelberger (1971), Fay (1975), and others may guide research and management of sites used for river recreation.

Resting or rotating sites or allowing users to stay only at designated sites have been suggested to protect or rehabilitate the soils and vegetation on heavily used areas. Managers are well advised to be aware of the difficulties associated with these management options before implementing them. They should be alert to the climate, soils, and vegetation and to the interrelations unique to their geographical location. Research and management guides useful in the Northeast may not work in the Lake States, and likely not in the arid West. For example, resting a site by merely preventing visitor use may restore vegetation in lush Eastern forest types. However, the dry and relatively sparse forest types of the Southwest may require planting or seeding, cultivation, fertilization, and irrigation along with extended closure if wornout sites are to be rehabilitated. Research has shown that such practices can be effective (Herrington and Beardsley 1970 , Beardsley and Wagar 1971 , Magill and Leiser 1972), and they may also be used to maintain recreation sites even during recreational use (Beardsley, Herrington, and Wagar 1974). In addition, site rotation requires suitable replacement sites for those being rested or retired. However, replacement sites may not be available, especially where good sites are rare and high recreational use has obligated most of the best ones.

Site protection goals allow river managers two courses of action, according to William Craig. They can allow camping anywhere or they can allow camping only at designated sites. If users are allowed to camp wherever they choose, impacts are spread over numerous locations in a wide area until high levels of use prevail. Then, the resource base may begin to deteriorate, recreational experiences may decrease in quality, and more intensive management may be needed. On the other hand, if use is restricted to designated sites, the resource base may be protected, but use must also be limited to the available space. This suggests the need for "capacity controls"--a reservation system--if the number of parties seeking entry exceeds the availability of sites. Computerized reservation systems are presently being used by several State park systems and on some western national forests with a high level of acceptance by users and managers (Magill 1976a , 1976b). Furthermore, capacity controls or other kinds of manual reservation systems are also being used to control wilderness use where camping is restricted to designated sites for resource and experience protection. A computerized reservation system capable of providing individual reservations has been proposed for wilderness use, but it has not been field tested.

The large attendance and keen interest at the "negative impacts" workshop demonstrated the recognition of managers and researchers of their need to work closely to develop scientifically based management for the protection and maintenance of our river recreation resource and the delivery of quality recreational experiences.

WORKSHOP #6

LAND MANAGERS ARE FINDING WAYS TO GET RESEARCH DONE WITHIN THEIR OWN ORGANIZATIONS

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The importance of this topic was emonstrated early in the symposium when ilton Krona, a park planner with the innesota Department of Natural Resources, tated: "Researchers give us answers to uestions we didn't even ask!" On the urface this comment would appear to be an ndication of gratitude; but the tone and ontext made it clear that the speaker was xpressing a widely held opinion that re-earchers are insensitive to the needs of and managers who are on the front line of ecisionmaking and land-use problems.

At the risk of creating conflict here it may not exist, I will suggest that and managers may even feel threatened by ivory tower" research which, more often han not, points a critical finger at the ay things are being done. An individual r agency that must deal with land use on day-by-day, crisis-by-crisis basis is nderstandably resentful of those who riticize without having the responsibility or the consequences of their decisions. n some cases the consequences may mean acing a judge in a court room.

However one views the issue, there is eneral agreement that a great deal more hould be done to integrate management and esearch. Only by working together can we ope to solve the complex recreation land-use roblems that are developing to crisis roportions. As Wilbur LaPage put it, the igns are encouraging, at least research s in demand. Land managers have put out he "wanted" signs.

There are numerous ways of improving he responsiveness of research to management roblems. The most obvious is to simply ave researchers and managers listen to each ther. However, a more structured approach s often felt necessary. Our workshop ocused primarily on a technique that might e labeled "in-house field research per-sonnel method".

Kenneth C. Chilman described how this system has worked in a field-based research program at Ozark National Scenic Riverways. He emphasized that the "in-house" model is especially applicable to small-scale, capacity-oriented studies. The field researcher is assumed to be knowledgable and well disciplined in his task. He brings with him the skills that will enable the management agency to: 1) initiate research, 2) evaluate research proposals, 3) nego-tiate contracts, and 4) interpret research results.

Leo F. Marnell described his experiences as a field researcher with the staff of Ozark National Scenic Riverways. His primary assignment was to document use through various monitoring techniques. This information was needed to help resolve immediate problems associated with in-creased use, safety, environmental impact, and conflicts between commercial and private users. The field researcher may also have the role of liaison or buffer between man-agers and the public, although Leo empha-sized that managers must have realistic expectations, i.e. they should not expect the research results to make decisions for them.

Randall R. Pope, former Superintendent of the Ozark National Scenic Riverways, provided insights into the manager's point of view. He stated that the increased use of field research personnel was largely a response to "crisis" situations. Tough decisions had to be made. These in turn had to be justified by data; pressure groups and the courts were demanding documentation to support management policies.

The discussion that followed the formal presentation helped to reveal some of the conflicts prevalent between research and management. Robert Knepper of Minnesota's Department of Natural Resources suggested that the primary value of research for man-

agement fell into two categories: 1) it enables managers to document use for purposes of allocation of resources and distribution of users, and 2) it provides insights into public perceptions and values that can help to refine management goals.

Perhaps we have used the term research in too broad a sense. The 1962 Outdoor Recreation Resources Review Commission (ORRRC) Report recognized three categories of research: 1) data collection, inventory, and factfinding; 2) applied management research; and 3) fundamental research. Some may argue that the first is not really research at all in that is merely involves the collection of information. Yet many of the same tools are utilized (e.g., sampling techniques, statistical analysis) and the same discipline and scientific honesty are required. Possibly these skills and attitudes are the major contribution a field researcher can provide to management.

The cardinal sin of the researcher is, of course, showing bias. He must deliberately and continually seek to avoid bias at all stages of the investigation process: structuring the research model, sampling, and interpreting results. In-house research presents some special temptations that must be consciously dealt with.

The manager has a tendency to seek information that will help him defend his established programs and alliances. He will also tend to interpret data in the same way--and research seldom produces results that are not subject to more than one set of conclusions. A management agency has an understandable desire to treat immediate problems (which are often symptoms) rather than underlying causes. Research directed toward the latter is more likely to lead to long-run solutions; however, it is also more likely to challenge the agency's basic assumptions and management policies. In other words, the problem illustrates a common forester's malady--"he doesn't see the forest for the trees".

Wilbur LaPage, Roger Clark, and Leo Marnell pointed out some additional problems with in-house research. The researcher may feel cut off from his colleagues and the stimulation and resources provided by a university environment. The kind of research required by management i not likely to be very glamorous or publishable. It may be beneficial to establ a modified reward system so that he is no so dependent on publications as a measure of his productivity. Publication may eve be discouraged by careful internal review deemed necessary because of the direct ma agement implications of research results.

Isolation can create other problems. One of the major shortcomings of much recreation research is the lack of comparability. In-house, small-scale researc may aggravate this problem. Perhaps a better communication network between researchers could do much to alleviate this condition.

All of this suggests that it may be well to consider a variety of ways to integrate research and management. At one end of the spectrum managers are simply exposed to research results produced by independent institutions or agencies. Thi sort of relation is probably best suited for research that challenges basic assumptions and long-range policies. At the sam time, other arrangements can be made to deal with the immediate needs of managemen These can range from the contracted job to the in-house research staff. In all cases the researcher must be provided with an environment of complete intellectual freedom--even if it means that at times management will get "answers to questions it didn't even ask".

As the workshop concluded, Uel Blank of the University of Minnesota agreed with an earlier comment that "No research is 'right'; we can't defend it with our lives". Perhaps the most important benefit that can be derived from a closer integrati of research and management is a greater appreciation of the limitations of researc. No research results are going to take the place of the manager's responsibility to deal directly with the resource and the people. Uel concluded his comments by suggesting that by working together, agreeing to the process and to the role of research results in decisionmaking, we can achieve a degree of harmony. This approach requires involvement of all partic ipants: managers, planners, researchers, politicians, and the public. If all are a part of the process all should be willing to accept the results.

WORKSHOP #7

MANAGING RIVER RECREATION USE OTHER THAN RATIONING

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To understand the intent of this workshop, a definition of rationing must first be developed since we wanted to look at nonrationing management options. *The American Heritage Dictionary* indicates that to ration is to "restrict to limited allotment". Applied to river recreation management, this means restricting human use of a river resource to some fixed upper limit, applied either to all users equally, or differentially to different groups or types of users. Implied is a problem of too much use for the capacity of the river. This, apparently, is one of the major concerns of river recreation managers and researchers.

Thus, the assignment for this workshop session was to explore ways to manage river recreation use by means other than by putting absolute ceilings on the amount of use, in total or by group, to be allowed upon a river. Even though we did not deal with absolute ceilings, it will be obvious to the reader that much of the discussion did focus on ways to moderate use pressures.

The moderator of the workshop was Carl Rust (Stanislaus National Forest, California). His challenge to workshop participants was to suggest viable nonrationing management options for dealing with the overuse problem. Joyce Nielson summarized the paper she and Bo Shelby coauthored and then the session was opened for suggestions from the floor for river use management.

The following paragraphs summarize the workshop participants' suggestions of management options and offer some reactions to Nielson and Shelby's paper and to the participants' comments. We point out how participants' emphasis on protection of the resource from overuse evolves into options for obtaining more benefit from the river resource. Some contradictions will be noted among the suggestions for river management options. These contradictions reflect apparently divergent, but healthily divergent, opinions concerning how managers should exercise their responsibilities.

SUMMARY LISTING OF SUGGESTED MANAGEMENT OPTIONS

Prevention of Overuse

Types of river recreational uses which interfere with one another can be separated through spatial or time zoning.

Heavy use can be limited by limiting the capacity of facilities and sites that are complementary to river recreation. These would include parking spaces, sanitary facilities, camping spaces, and access points. This is better than zoning because of the negative attitude people often have toward zoning.

Natural barriers or constrictions can be used to effectively limit use to reasonable levels. Too often managers remove thorny or noxious species of plants, dynamite constrictions in the rivers, eliminate aggravating insects or otherwise remove natural constraints on use pressures. Managers may even see a need to "create" some of these barriers.

Where dams exist upstream, amount and type of use can be influenced by controlling the level and periodicity of river flow.

What people expect and perceive and how they behave on rivers can be influenced through promotion and advertising; e.g., selective dissemination of information describing such things as types of opportunities and "crowding" conditions. Sometimes publicity must be avoided because of the chaos it creates.

Charging a user fee will limit amount of use. Varying the amount of the fee can help to level out the peaks and valleys of use pressures.

There is a need to take a long-range look at current cases of overuse. There is a distinct possibility that heavy-use conditions may be short lived because of probable future shortages and fuel rationing. Thus, care should be exercised in implementing long-lasting solutions to potentially short run, heavy-use problems.

Levels and types of use can be controlled by prohibiting certain activities on a river system.

Increasing Benefits to Users

Keep the attention that is focused on "wild" rivers in proper perspective. Often too little attention is given to all the other rivers, even though they comprise about 97 percent of our total river resource. Emphasize greater use and satisfaction from nonwild rivers.

A first step in river management for recreation is to understand the users' wants and the resource's capabilities. From this, meaningful management objectives can be established that will greatly help humans benefit from river resources.

Once meaningful objectives are defined, managers should stick to them and not become caught up in cycles of change that reflect every fad that surfaces. As Nielson and Shelby have pointed out, "It is [very] possible that user preferences and attitudes grow out of the kinds of experiences managers provide". Consistent management aims should enhance user satisfactions as well as reduce management complexities.

Managers need to be more observant of user behavior. We know that people adjust their behavior and maybe even their attitudes according to situations encountered. With the help of researchers, we need to find ways of satisfying users more and protecting the resource through a knowledge of behavior.

One way to reduce dissatisfactions is to group homogeneous or compatible types of users. This will help lessen distasteful user interactions.

An option we should always keep in mind is doing nothing. Sometimes it is obvious that too much management is worse for enhancing user experiences than doing nothing at all.

Site hardening can be used to effectively eliminate some of the problems which managers perceive as being caused by overuse. Instead of reducing use to make it compatible with existing resource conditions, consider modifying the site to accommodate more users.

Managers sometimes become too confident with standards or principles of management that may no longer be viable. Management should not become so stagnant that obvious indicators of needed change are overlooked. Preferences, management technology, recreation equipment, and environmental conditions do change.

There is need to explore more ways of using rivers for recreation. For example, rivers may be considered a means of access to historical, archaeological, and recreational experiences or other participatory opportunities along their banks. In this case, the way the river is managed and developed will be different than if the river is viewed as the recreational end in itself.

COMMENTS CONCERNING THE MANAGEMENT SUGGESTIONS AND THE PAPER

Two different philosophies or schools of thought seem to exist in the above statements regarding management of rivers for recreation. First there is the school that places emphasis on limiting amount of use. This school appears to conceive of the river resource as a place to experience a unique, wilderness-oriented recreation experience. As such, the focus in management is on techniques that will protect the integrity of the resource and at the same time create conditions that would tend to maximize the average level of user satisfaction. Under this philosophy, pressures for greater use of a river are viewed as a constraint on goal achievement.

The second school of thought seems to focus attention on an array of recreation uses of rivers that is broader than just wilderness-oriented experiences. Though protecting the wilderness integrity of the

iver resource is within their list of management options, they also are open to the ore intensive uses. The goal of this chool is to *maximize the sum of user atisfactions* derived from river recreation xperiences.

The preceding listing of management ptions suggested by the managers attending his workshop has been divided roughly into he two schools of thought. The eight uggestions for preventing overuse offer bvious promise with broader application nd testing. But a point for some concern s that there was no really strong evidence rom the statements made during the workshop hat a clear management objective had been onceived. It is very likely that many of s strongly reflect our personal biases or "proper" use of a river resource when e begin to define our management options. n this case that bias was toward low evels of use.

While this certainly is not an improper philosophy or attitude, it must be ept in proper perspective with respect to he full range of recreational experiences hich river users or potential users may ant. Management of a public resource must e undertaken with a responsible openness o a wide range of potential uses, only ne of which is wilderness oriented.

Under the options headed "Increase enefits to Users" the theme of undertanding more about the actual and potential ser and employing this information to set anagement objectives is prominent. This heme, of course, is aimed at maximizing otal recreation satisfactions. The on-site anagement procedures offered were directed t manipulating the resource--within eason--to fit user needs.

Although the goals underlying these wo schools cannot and should not be viewed as antipodal, they do lead to different management strategies and actions. Too often misunderstandings develop because it is not clear which goal management is trying to achieve. Usually only general statements of goals can be ascertained such as, "we're managing for user satisfactions".

This lack of specificity in defining the satisfaction-achievement goal was also evident in the Nielson-Shelby research. It is obvious from the measurement technique used that average level of individual user satisfaction was the variable of concern. Yet some of the commentary within the paper seemed to deal with the sum of the satisfactions achieved by all users. For example, conclusion #1 on page 177 states that "Managing for user satisfaction implies extremely high density levels". If the management goal is to maximize aggregate satisfactions, then this statement is true. If it is to maximize the average, per-user satisfaction, then this conclusion probably is not true.

It is important that the goal of achieving satisfaction be clearly articulated if proper management actions and attitudes are to be adopted. This is particularly true with respect to actions which directly govern use levels (fig. 1).

Assuming that the shape of the total satisfaction function is reasonably correct, it can be seen that if maximization of the average level of individual satisfaction is the goal, then managers should indeed seek to limit use amounts to "a" so that overcrowding can be avoided. But if maximum total satisfaction (summed individual satisfactions) is the goal, then use amount "b" should be sought. The amount of use represented by "b" is almost twice the amount represented by "a". Policies and management would be very different for achieving one or the other of these two goals.

The need for clear definitions of goals is exemplified here and meeting this need could reduce misunderstandings considerably. In addition, and perhaps more important, a clear understanding and articulation of the management goal enables management to be assessed more objectively and makes selection of management options more defensible. Thus, if the goal is to maximize the average level of satisfaction among users (which goes hand in hand with maximum resource protection), then the first set of management options should be emphasized. If the goal is to obtain the highest level of aggregated user satisfactions, then the latter set of options would receive more emphasis.

Several references were made to social carrying capacity during the workshop and in the research paper. Most of these further indicated lack of clearly defined management goals. A principle well worth repeating

is that *carrying capacity cannot be determined* if goals are not first established and clearly defined. For example, if the goal is to maximize average satisfaction per user, then the social carrying capacity

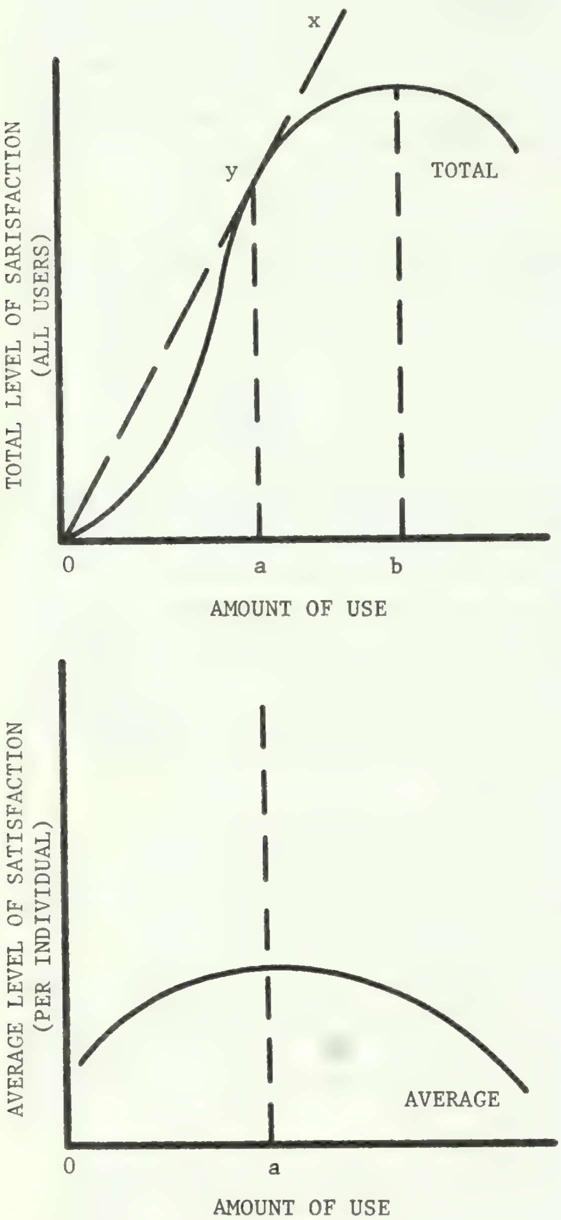

Figure 1.--*Relation between total and average levels of satisfactions and amount of river recreation use. (The average satisfaction level is graphically calculated by extending a ray (0x) from the origin of the total satisfaction curve (0) to its point of tangency (y) with the total satisfaction curve.)*

of a river would be "a" (fig. 1). If th goal is maximum total satisfaction, then the capacity of a river would be "b" (fig. 1). Thus depending on the adopted goal, the social carrying capacity of th same river could be greatly different.

OTHER OBSERVATIONS CONCERNING THE NIELSON-SHELBY PAPER

It is obvious that the reported research makes a valuable contribution to the kind of river recreation and resourc situation addressed. Some potentially important insights into recreationists' behavior are offered. But it is not obvious how far we can go in applying these results to other situations or environments. The Grand Canyon is a very unique resource and it is likely that us motivations there differ substantially from the motivations of users of other, less-renowned rivers. For example, Conclusion #2 on page 177 indicates that att itudes and preferences seemed to develop during the recreation experience. The uniqueness of the Grand Canyon river run and the fact that not many people ever experience this kind of excursion makes lack of well-articulated expectations an preferences very understandable. For other, better known types of rivers, att itudes and preferences may well be much more in evidence.

There is an apparent need for simil research on a broader array of river envi ronment types. With the kind of information provided by Nielson and Shelby many of our management decisions can be made more objectively and defensibly. This ki of research should answer two important questions.

First, how do we reliably measure user satisfaction? Some progress has bee made, but we still find it very difficult to interpret the satisfaction measures us. We not only need to know whether a person is satisfied, but we also need to know hc satisfied. We further need to be able tc aggregate satisfactions for groups of users. As was pointed out earlier, the assumption that maximizing the average level of satisfaction automatically leads to maximum aggregate or total satisfactio simply has no basis.

Second, how do we indicate the shape

of the total satisfaction function? In figure 1 a sigmoid shape is shown. Despite some evidence to support this shape, it still remains largely an assumption. Knowledge of the amount of change in satisfaction that occurs per unit of increase in use is necessary for evaluating the tradeoff between use loadings and satisfactions. This, of course, is a first step in assessing the consequences of alternative policies and management practices designed to influence amount or kind of river recreation use. It is strongly recommended that research such as that by Nielson and Shelby explore the direct relation between amount of use and satisfaction levels. For example, on page 170, last paragraph, an indirect correlation (or lack of it) is discussed. Determining the direct correlation between user satisfaction and amount of use would have been much more meaningful and usable. The next step should be an attempt to measure the actual function.

WORKSHOP #8

THE FUTURE OF STATE AND FEDERAL WILD AND SCENIC RIVER PROGRAMS

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The historical background and status of the Wild & Scenic Rivers Act was reviewed by Mr. Eastman in his paper: "River preservation and recreation programs--a status report". The paper generated the following discussion.

Upon enactment of the Wild & Scenic Rivers Act the Secretaries of Interior and Agriculture agreed that additional criteria were needed in carrying out the Act. It was realized that: (1) The established wording of the Act needed more specific explanation, and (2) definitions were needed for the extent, geographic distribution, and balance of the three types of rivers (recreation, scenic, wild) to be included in the system.

Since the Wild & Scenic Rivers Act was passed in 1968, specific guidelines have been developed by the two Secretaries. Additional direction has evolved through the study process and will continue to become more definitive as more studies are completed. However there is a real need to determine the extent, the geographic distribution, and the balance in wild, scenic, and recreation rivers for the nation as defined by the Act; and to recommend to Congress those rivers that should be studied for possible inclusion into the System. To answer this need the Bureau of Outdoor Recreation (BOR) has begun to inventory and classify all significant rivers or river segments 25 miles or longer that appear to be free from impoundments, have acceptable water quality, and provide for a quality recreation experience. The objective is to uniformly evaluate all significant rivers in the U.S., and to develop a "Minimum System" list of rivers that can be recommended to Congress for study. The "Minimum System" list, in addition to providing a systematic approach for determining the extent, geographic distribution, and type balance, will provide the Office of Management and Budget with valuable information in determining the appropriate dollars to be used for river studies.

The inventory and evaluation of the rivers will be carried out with full involvement of the public, private organiza tions, and State and federal agencies, be fore a recommended list is submitted to Congress. There will be at least two opportunities for the public and concerne agencies to become involved in the proces It is hoped this will be during the "filtering" stage, when rivers will be ra according to their desirable qualities rather than after the Minimum System list has been finalized.

The recommended list will not preclu other rivers from being nominated for stu or inclusion into the system. Instead, i will provide a reliable information sourc for evaluating all significant rivers in the country, and rank those recommended for study. A river may "filter out" as a low priority, yet Congress or a State may see fit to study or include it in the appropriate river system. If several riv within the same locale are rated equal, a of these rivers could be forwarded to Congress for consideration.

In Fiscal Year '77 BOR received sufficient funding to concentrate on an inventory of rivers east of the Mississippi. Public input for these rivers will probabl occur in early summer of 1977. It is hoped that BOR will be financed to extend the inventory to the western half of the nation in Fiscal Year '78.

There has been some question and perhaps confusion as to the need for the "5-D" river category that now exists. Since the establishment of the Act, a number of the original 5-D rivers have bee added to the "study category" and addition

ivers have been placed in the 5-D category. he National Environmental Protection gency (NEPA) requirements for environmental tatements and the Water Resource Council equirements for adherence to the "Prin-iples and Standards" have provided some rotection for rivers in the 5-D category. owever, it appears that the 5-D category ill continue to serve a useful purpose upon ompletion of the Minimum System list. hile the Minimum System list will emphasize he top rivers recommended for study, the -D river category will focus attention on ther rivers that may be worthy of study.

The advantage of maintaining a 5-D ist is that is has legislative importance, ssuring the public that this list cannot e easily overlooked by agencies who may e considering river uses not compatible ith the Act. It also encourages the in-olved agencies to closely coordinate their iver planning and projects with others to chieve the best public use of the river orridor.

State river programs have a wide degree of variance, with some States being very active in their own or federal programs, and other States having no program at all. In some cases, the federal study program has stimulated State programs or sharing in the program with the federal government. Because no two State programs are alike, it is difficult to generalize as to how some States can be motivated to participate in a river program. Two methods suggested during the workshop were: provide special federal funding in addition to the Land and Water Conservation Fund, or increase the ratio of Federal to State contributed dollars in the Land and Water Conservation Fund program.

In addition to the preceding discussions, Dr. Claude E. Terry illustrated with slides, "A filter system for determining river suitability for national wild and scenic river status". A copy of his paper is included in the Symposium Proceedings.

WORKSHOP #9

MANAGING RIVER CORRIDORS IN MULTIPLE OWNERSHIP

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The purpose of this paper is to summarize key issues, ideas, and discussion topics that were covered during the Symposium Workshop on "Managing Corridors in Multiple Ownerships". The session was chaired by Michael Priensnitz, Supervisor, River Section, Minnesota Department of Natural Resources. Priensnitz and James Harrison summarized the workshop introductory paper contained in this Proceedings. Henry Goetz, Manager, Lubrecht Experimental Forest, Greenough, Montana, and Jerry Stokes, Outdoor Recreation Planner, Bureau of Outdoor Recreation, Denver, Colorado, also discussed their experiences related to managing rivers in multiple ownerships. As session recorder, I have attempted to summarize my impressions of what transpired during the workshop. No attempt will be made here to identify comments of individual workshop members, rather, this should be reviewed as a product of all workshop participants.

River planners and managers are often confronted with the seemingly insurmountable problem of organizing, developing, and managing river corridors under conditions of multiple ownership. Indeed, it is a rare occurrence when all land along a river corridor is under a single ownership. Thus, the river manager is more often than not confronted with the problem of forging a chain that is made up of links owned by different people. The manager knows that a single weak or missing link will cause failure of the entire river management and preservation system.

Although managing rivers in multiple ownership corridors is an exceedingly difficult job, workshop participants felt that it can be accomplished if the manager is willing to make the necessary effort.

But there are no easy solutions. To even approach the problem, we must recognize that individual land owners, each acting in their own best interest, do not guarantee preservation of a river. Rather, an environment must be created that allows individual owners to cooperate and act in the long-run collective interest. It is the job of the river managers to create this environment.

In trying to get individuals to act together, the river manager must realize that individuals are self-oriented. Yet, a way must be found to foster mutual cooperation. Individuals must understand that nobody really owns a river. Although numerous laws and institutions establish rights to river ownership, in the long run nobody really owns a river, and nobody is really responsible for what happens to it. River property owners need to understand that they all share mutual responsibility for river preservation.

Thus, an overriding issue exists in the trade-offs between individual freedom of choice inherent in property ownership, and collective freedom and long-term land stewardship. When discussing long-term preservation of a river corridor, we must talk about a desirable balance between these two extremes. Such a balance must be weighted toward collective freedom if a river is to be preserved.

NEW SYSTEM OF SOCIAL ACCOUNTING NEEDED

The system of laws and institutions that govern river management developed under conditions of resource abundance. The problem then was a general scarcity of goods, and resources were used freely to produce these goods. Concern for resource preservation was minimal. These same laws and institutions that were forged to solve problems related to an expanding frontier, underutilization of resources, and need for economic organization, govern actions of today's river manager who must search for solutions to problems related to a

losed frontier, scarcity of resources, nd the need to manage for social amenities.

Existing institutions do not provide echanisms that allow or motivate individals to act collectively; even if they esire to do so. Individual acts committed or the public good go largely unrecognized. he river manager must consequently work ithin a largely inflexible institutional tructure to achieve the goal of long-run iver preservation.

What is needed is a new social accountng system--a system that allows individals to achieve their own objectives while lso achieving broader, social objectives. uch an accounting system must be based on nstitutional arrangements that overcome livergence in perceived individual interest nd the larger collective interest. The anager must try to strike this balance in egotiating programs to preserve and manage ivers.

It is difficult to visualize a new ystem of social accounting that would not rode individual freedom. Hardin (1968) rgues that such a system must be based on utual coersion that is mutually agreed pon. This idea is not new. Societies hroughout history have set up mutually oersive systems to allow maximum collective reedom by curtailing individual freedom. ur system of domestic and international aw provides the framework that guarantees ollective freedom, yet the system represents a form of coersion, mutually agreed pon.

In dealing with multiple owners, the river manager must foster a spirit of cooperation, where all owners will agree to give up some of their ownership rights for the benefit of the whole. But the agreement on which the cooperative effort is based must be clear to all and must treat all individuals equally. Where individual rights are unreasonably affected, the individual must have recourse and be eligible for just compensation.

Ultimately, a new system of social accounting must be based on a redefinition of common property. Regarding rivers, the definition must recognize that all of us, but not any one of us, have claim to a river resource. Such a system would be predicated on the understanding that collective resources are finite and increase in value as population increases.

ORGANIZING FOR ACTION

Know the Cause for Action

As Schelling (1971) points out, under the immediate pressure of extreme emergencies, people can be expected to act together to their mutual and individual benefit. But if there is nothing heroic, no apparent need for coordinated effort, most people will only cooperate half-way.

In approaching the problem of organizing river management under multiple ownerships, the manager must understand that people will not cooperate unless there is some threat to their own personal interest. Once identified, the manager who is trying to organize cooperative effort can use the issue to promote mutual action. Workshop discussions indicated that the issue to stimulate mutual action can originate from many directions--pressure for commercial development, government or citizen group pressure to designate as a wild and scenic river, or plans to physically change the river itself in a significant way. Whatever the issue, it must be of sufficient concern to all owners involved to get them to act together to their mutual benefit. This issue will serve as the call for action and should be understood by all involved.

Get All Interests Involved

Decisions regarding designation and management of a river have far-reaching impacts. In trying to organize action, the river manager must be sure that all interests are represented and have input into the decision and planning process. Participation of diverse interests cannot be forced, but by providing information and inspriation, the river manager can get most interests involved. It is important that nobody be forgotten and that special attempts be made to involve diverse interests. Where such diverse interests exist, a system should be developed to provide compensation where particular groups or individuals are adversely affected. Channels should also be established to provide arbitration of individual grievances.

Decide How To Organize

There is no best method to organize land owners or river management councils.

Workshop participants discussed various approaches that proved successful under specific conditions. Land owner corporations, land owner coalitions, land trusts and conservation easements were presented as alternative ways to organize land owners toward achieving a mutual goal. Whatever system is used, it must treat each individual involved as an equal and ensure that all have the chance to have an input. Additionally, the system must insure that all owners act together and equally share risk.

Once a system for preserving a river in multiple ownership has been devised, a mechanism must be developed to manage the river. Again, this can be accomplished in many ways, depending on circumstances. Advisory boards, councils, public commissions, government, etc., were discussed as alternative approaches. Whatever system is used, careful thought should be given to the decisionmaking body's advisory or regulation function. Also, the means by which individuals are appointed to the management body need to be carefully considered. Whatever system is used, its responsibilities, scope of activities, and authority must be defined at the outset.

What Incentives Can Be Provided?

Frequent divergence occurs between what people are individually motivated to do and what they might choose to do collectively if given a choice. Individual owners of river corridors must be given an incentive to act together. The problem of self sacrifice in the public interest becomes particularly severe when the individual who acts unselfishly in the public interest finds his neighbor reaping a financial benefit because of his unselfish act. A rational individual response would be to maximize personal gain by getting other owners to act in the "public interest". Unselfish individual acts in the public interest are easily thwarted, and an accelerator effect in the opposite direction may occur.

The river manager must be sure that sufficient recognition and incentives are given to individuals who act unselfishly. But the available incentives are limited. Community recognition may be among the most useful. Tax incentives through reassessment of property values, differential rate structures, or reduction through tax deductible contributions are alternative incentives. Less direct incentives include personal involvement in a project beneficial to the community, involvement in the planning and management process, and rewards obtained through mutual accomplishment. The river manager must rely on all of these incentives to obtain mutual cooperation. But whatever he does, he must remain sincere in his efforts to obtain cooperation.

The River Manager's Responsibility

The river manager occupies the central leadership role in organizing river preservation and management systems. As a public servant, the river manager is given the responsibility to coordinate diverse interests. In this role, he must facilitate activity, rather than direct it. He must act as a missionary in a foreign land, always meeting people on their own terms. In his dealings with land owners and the community, he must establish credibility and foster a spirit of mutual cooperation.

Perhaps more than anything else, the river manager must understand that he is dealing with human nature. He must understand that most individuals act to foster their own best interests. The river manager must try to direct these interests toward collective goals, but he must realize that he cannot change human nature. Rather, he must get individuals to look beyond themselves in achieving long-run collective goals.

SUMMARY

In summary, workshop participants agreed that managing rivers under multiple ownership is a difficult but not insurmountable problem. If the right incentives are provided, if owners are informed and involved, they will generally cooperate. Collective action to achieve river preservation is preferred to outright public purchase, which often creates controversy and discord.

SYMPOSIUM SUMMARY

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ATTENDANCE

Nearly 400 people showed up for the first-of-a-kind symposium on river recreation management and research. This attendance far exceeded the expectations of the symposium planners and was strong evidence of the high level of interest in the topic of river recreation, especially in light of the well publicized severe winter weather that had gripped the eastern and mid-western parts of the country. It seems fair to assume that the 400 people came to Minneapolis in January in response to unmixed professional motivations. Even widespread drought that greatly reduced flows in many streams apparently did not dry up interest in river recreation.

The discussions also revealed a high degree of interest. There was never a lull, and session moderators had their hands full trying to field the constant flurry of questions from the floor in a fair and orderly way. Even in the waning hours of the symposium the attendance remained high; the usual dwindling of the audience was not evident. Similarly, almost no one delivered a paper and then slipped away, as is all too common at such meetings.

Evening sessions were developed on a volunteer, unofficial basis by a number of conference participants. Attendance was surprisingly good, another tangible indication of the deep interest in the subject of river recreation.

Symposium participants were diverse as well as numerous; geographic representation was widespread. Almost all States and most Canadian provinces were represented. A map near the registration desk was covered with red pins showing the origin of participants--a remarkably wide, even distribution. Two persons from Anchorage, Alaska, took the prize for long-distance travel.

Participants were also diverse in terms of interests and affiliations, although there were some gaps. Government river managers were numerous, representing Federal, State, and special, local districts. Lawyers were there, as were university professors, students, and government researchers. Commercial outfitters, especially from the western white-water rivers, were out in force, but some other segments of the private outfitting industry had little or no representation. Private river runners and their organizations were present, but probably under-represented proportionately. (The lack of expense accounts might be a partial explanation for the shortage of representatives of the private parties.) Absent or very scarce were representatives from some groups with major roles in river recreation--including politicians, river developers and dam builders, equipment manufacturers, youth-serving organizations, and organizations representing urban people and their needs.

GENERAL IMPRESSIONS

The symposium reflected careful planning and much hard work in advance. The preliminary proceedings, including all tha papers, was sent to all participants who pre-registered. Despite a wry comment by Tom Heberlein that this procedure resulted in a high level of "collective guilt feelings" because of failure to read the proceedings in advance, it was my impression that many people had done their homework and the floor discussions showed it.

Papers were summarized, not read, and this worked reasonably well. Most authors highlighted major points effectively within the limited time allotted to them.

Discussions were always active and searching, although there were a few speeches from the floor disguised as

questions. Generally the questions and exchanges of viewpoints were constructive and reflected mutual respect, although acrimony was not entirely absent and at least once the questioning resembled a Perry Mason cross-examination.

It seemed to me, and a number of the workshop reporters as well, that the symposium was a success. I conducted a thoroughly unscientific survey in the halls during breaks and the evaluations were unanimously favorable. I think most of us learned a good deal about a new subject. There is great regional variation in river recreation situations, and this was the first time people had gathered from such a large area to exchange their ideas and experiences.

I thought I sensed some increased understanding and even a little added empathy for "the other side". It was hard not to appreciate just how difficult a position river managers find themselves in, especially if use must be limited. It was also clear that conscientious outfitters face a difficult, changing situation. The growing numbers of private parties also are up against tough problems.

The broadened horizons and empathy were the main results of the symposium, I think, along with many valuable new contacts for future communication. Group conclusions and resolutions were not sought and would not have been appropriate, especially at the first symposium on such a complex, rapidly evolving topic.

The workshops were useful, but the unexpectedly large attendance forced them to become something more formal than workshops. More than 100 people attended most workshops, and that many people with only a little more than an hour available just cannot function as a workshop. However, there were more in-depth discussions of specific topics than were possible in the general sessions. Perhaps if the large attendance had been foreseen, more workshops might have been scheduled.

The program and the papers were better balanced than the discussions. Perhaps because of the background of many of the participants or maybe because of the perception of what are the most pressing current problems, the discussions tended to concentrate on rivers in wilderness-type settings and largely overlooked the intermediate, pastoral, and urban rivers. Several of the workshop reporters also saw this wilderness emphasis in discussions, despite a number of good papers and interesting oral summaries of the urban end of the river recreation opportunity spectrum.

SPECIFIC THEMES DEVELOPED

The emphasis on wilderness was related to the strongly recurring theme of allocation, i.e., for a river on which use is rationed (and these are generally wilderness-type rivers) how is the permitted use allocated to different classes of users--specifically, how much is allocated to commercial outfitters and how much to private parties? This problem surfaced in Roderick Nash's opening paper, kept recurring in other papers, and was vigorously debated from the floor. (Several people seemed to have attended the symposium mainly to defend or enlarge the allocation to their interest group.)

As George Stankey points out in his report on the rationing workshop, allocation is a normative question and is inherently a political issue, largely outside solution by either managers or scientists. However, there surely are aspects of the issue that research could clarify, and opportunities for objective knowledge to narrow the range of disagreement and to single out the normative value judgments from what are basically questions of fact. It was unfortunate that little discussion was aimed at identifying the researchable components of the problem, for, obviously, the symposium was not intended to decide on the politics of allocation.

Another overriding theme throughout the sympsoium was the complexity of the river recreation environment. To a degree usually unequalled elsewhere, rivers are enmeshed in an intricate web of mixed legal jurisdictions, management responsibilities by numerous agencies, diverse ownership, and conflicting recreational and commodity users.

Concepts of rivers as recreation resources have themselves changed drastically in recent history, adding to the complexity of the situation. Rugged, white-water rivers, especially, have been redefined in a revolution in resource perception, described by Roderick Nash. A few decades ago such wild rivers were viewed as dan-

rous, foreboding, and unnavigable. Con-olling and harnessing them seemed to be viously desirable. Changing ideas, new uipment, and development of new skills d to exploding recreational use and grow-g concern for keeping some rivers free-owing.

As a result, use pressures are mounting a finite, dwindling resource, a point de by Darrell Lewis the first morning d many other symposium participants. is situation is the basic source of the ver recreation management problem.

Another key idea, expressed several mes by different people, but usually ther quickly forgotten in discussions, the need to consider individual rivers a broader context of a system of rivers. system of rivers must provide diversity types of use, amounts of use, level of velopment, and nature of the landscape tting. How to define a balance in types opportunities within a diverse river stem is a critical question.

The need to define clear, specific nagement objectives for individual rivers s emphasized often during the symposium, t there was also agreement that this has ually not been done well. Management jectives must be the starting point for y consideration of carrying capacity. pacity is not an intrinsic quality in-rent in the rivers--a number that exists, iting to be discovered. It is a more mplex concept, basically an assemblage impacts on resources and recreational periences resulting from a given pattern d level of use that are acceptable in e light of management objectives, in-nsity of management, visitor behavior, sitor perceptions, and site characteristics.

There was much interest in improving sitor behavior to reduce impacts and, effect, raise capacities by developing system to license river runners. taining a license would require proof the would-be river runner's knowledge d skill. The details of operating a cense system could become complicated, it the general idea seemed to be favored many symposium participants.

Tom Heberlein, Joyce Nielson, and Bo elby reported that, at least for some vers, social carrying capacity may be ss clearly defined than in other settings udied. Particularly on the Colorado River in Grand Canyon, visitor expectations in terms of solitude were not well crystallized and satisfactions were not strongly influenced by numbers of other visitors encountered. The symposium participants found it hard to believe that crowding and loss of solitude were not still important, and the consensus, reflected in Ken Cordell's workshop report, seemed to be that further research, especially on a wider range of types of rivers, was needed. Concern was also expressed about the need to consider individual, as opposed to aggregate, satisfaction related to congestion. The authors concluded that maintaining certain levels of solitude was desirable, but that social norms, rather than satisfactions, were the key to defining optimum solitude levels. This conclusion seems to bring their work back into the mainstream of previous wilderness carrying capacity research.

Management of river recreation is potentially complex. Many aspects of the setting and its use can be influenced by management in various ways. For example, there are many alternatives to rationing use that deserve thorough exploration by managers before they resort to such restrictive actions.

There seemed to be agreement that river recreation management is in its infancy. Not only has it suffered from a lack of clear objectives, but it has tended to be reactive to crises rather than leading. As management develops and matures, increased coordination will be necessary because of the complex mixture of jurisdictions. The Western Interagency Whitewater Committee is an example of a response to the coordination need for one region of the country.

The roles of public agencies and private businesses, landowners, and organizations are still not well defined, and some sharp differences of opinion on this issue surfaced at the symposium. Many assumed that governmental control was the obvious approach to most if not all river problems. This view was challenged; for example, Wilbur LaPage said, "If you say you don't trust private interprise you are only admitting you are incompetent to work with the private sector."

The necessity for involving the public in government decisionmaking for river recreation was generally recognized. The

public must play a major role in defining objectives, evaluating management policies and actions, and weighing the tradeoffs involved in many decisions. Agency personnel seemed to accept this role for the public and to see involving the public effectively as a professional responsibility. There were some interesting examples of public participation, particularly the Georgia experience described by Claude Terry.

There were occasional reminders from the audience of the need to be concerned about the loss of free-flowing rivers as a result of dams, diversions, and ground water depletion, but the momentum of the discussions focusing on immediate or short-range river recreation management problems seemed too strong to overcome, and the preservation issue continued to be shortchanged.

River recreation needs to be put in perspective, to be viewed as a part of larger systems. It is one part of an outdoor recreation system, which in turn is part of a much larger system intended to meet a variety of human needs. Temporarily, in focusing on rivers, I think we forgot all about the larger systems they fit into.

Research needs surfaced constantly. One of the most obvious is for basic descriptive data, especially of recreation use. One workshop concentrated on recreation use measurement. Better knowledge of the benefits derived from river recreation and how management affects them was also a common theme, often related to the capacity issue and also the allocation issue. For example, do visitor benefits increase with greater self-sufficiency during the visit? At times, as a researcher, it was a bit disconcerting to see how much was being expected of research, as though some man- agers had confused scientists with wizar But, then there were jolts of healthy skepticism, as some managers stressed th need for research's aid in developing practical managerial tools that could pa some sort of cost/benefit test. But, it is important for all to remember that re search results will not make the manager decisions for them--research can only provide a better understanding of the probable consequences of different actic or events and improved knowledge of processes. Managers must still make the decisions in light of objectives and con straints, making use of information from research.

THE FUTURE

This first symposium on river recrea tion was, on balance, unusually sucessfu and made a good start in improving both river recreation management and research contribution to it.

The symposium could lead, and I hop it will, to continued communication amon managers, the public, and research scien tists. This communication should lead managers to consider a wider range of policies and actions and choose those th most effectively provide benefits to people. Better communication should als contribute to expanded, improved, and more relevant research.

If the symposium has any of these results, it was indeed unusually success

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